Associations of the Stair Climb Power Test With Muscle Strength and Functional Performance in People With Chronic Obstructive Pulmonary Disease: A Cross-Sectional Study

Marc Roig, Janice J. Eng, Donna L. MacIntyre, Jeremy D. Road, W. Darlene Reid

Background. The Stair Climb Power Test (SCPT) is a functional test associated with leg muscle power in older people.

Objective. The purposes of this study were to compare the results of the SCPT in people with chronic obstructive pulmonary disease (COPD) and people who were healthy and to explore associations of the SCPT with muscle strength (force-generating capacity) and functional performance.

Design. The study was a cross-sectional investigation.

Methods. Twenty-one people with COPD and a predicted mean (SD) percentage of forced expiratory volume in 1 second of 47.2 (12.9) and 21 people who were healthy and matched for age, sex, and body mass were tested with the SCPT. Knee extensor and flexor muscle torque was assessed with an isokinetic dynamometer. Functional performance was assessed with the Timed “Up & Go” Test (TUG) and the Six-Minute Walk Test (6MWT).

Results. People with COPD showed lower values on the SCPT (28%) and all torque measures (~32%), except for eccentric knee flexor muscle torque. In people with COPD, performance on the TUG and 6MWT was lower by 23% and 28%, respectively. In people with COPD, the SCPT was moderately associated with knee extensor muscle isometric and eccentric torque ($r \geq .46$) and strongly associated ($r = .68$) with the 6MWT. In people who were healthy, the association of the SCPT with knee extensor muscle torque tended to be stronger ($r \geq .66$); however, no significant relationship between the SCPT and measures of functional performance was found.

Limitations. The observational design of the study and the use of a relatively small convenience sample limit the generalizability of the findings.

Conclusions. The SCPT is a simple and safe test associated with measures of functional performance in people with COPD. People with COPD show deficits on the SCPT. However, the SCPT is only moderately associated with muscle torque and thus cannot be used as a simple surrogate for muscle strength in people with COPD.

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Chronic obstructive pulmonary disease (COPD) is a clinical condition with numerous systemic manifestations[1] that compound the loss of function commonly observed in people with this respiratory disease.[2] Skeletal muscle dysfunction has recently gained recognition as an important systemic effect of COPD that contributes to functional limitations in people with COPD (for a review, see Mador and Bozkanat[3]). In COPD, skeletal muscle dysfunction is characterized by deficits in muscle strength (force-generating capacity) and endurance,[4] muscle atrophy (ie, reductions in muscle mass),[5] and alterations in muscle composition (eg, increased intramuscular fat).[6] The relevance of assessing muscle strength in people with COPD has been emphasized in recent studies. For example, Decramer et al[7] found that knee extensor muscle weakness was a useful measure of health care resources in people with COPD. More recently, knee extensor muscle strength was identified as a simple and powerful predictor of mortality in people with COPD.[8] Other studies have confirmed the clinical importance of assessing muscle strength as an important factor associated with exercise capacity in people with COPD (for a review, see Debigare and Maltais[9]).

Muscle strength in people with COPD traditionally has been assessed with either isokinetic or isotonic dynamometers. However, most of these devices are large, expensive, and not accessible to clinicians and often require procedures involving complex and time-consuming protocols. Recently, more-sophisticated methods for assessing muscle activation, such as femoral magnetic stimulation, have been made available.[10] These techniques are appealing to researchers because they permit potential confounders related to the volitional capacity of an individual to be minimized and thus reduce testing variability. However, these methods also require specialized equipment that can be impractical in clinical settings. Therefore, alternative means of assessing functional muscle performance in people with COPD are needed.

The Stair Climb Power Test (SCPT) recently was proposed as a simple and safe measure associated with measures of lower-limb muscle strength, power, and functional performance in older adults.[11] Because the SCPT does not require additional equipment, it could be a reasonable alternative to more-sophisticated tests for measuring lower-limb muscle impairments in people with COPD. We conducted a cross-sectional study with the primary aim of comparing the results of the SCPT in people with moderate to severe COPD and people who were healthy (control group) and matched for age, sex, and body mass. The secondary aim was to determine associations between the SCPT and measures of muscle strength and functional performance. We hypothesized that people with COPD would show lower values on the SCPT than people who were healthy and that the SCPT would correlate with knee extensor muscle torque. We also hypothesized that the SCPT would show moderate correlations with measures of functional performance.

Method

Participants

People with COPD and people who were healthy (control group) were recruited on a voluntary basis in the local community from October 2008 to June 2009. Information about the study was distributed in waiting rooms of hospitals, pulmonary function laboratories, and community and senior centers in the area of Vancouver, British Columbia, Canada.

The inclusion criterion for people with COPD was moderate to severe disease (stage II or III), as determined with the Global Initiative for Obstructive Lung Disease.[12] Exclusion criteria were an acute exacerbation[13] within the 3 months before the study; regular participation in a formal exercise rehabilitation program during the 1-year period before the study; current smoking; comorbid cardiovascular or neurological disease or lower-extremity musculoskeletal problems that could interfere with or could cause undue risk during the performance of a study test; use of portable supplemental oxygen on a continuous basis; and α_1-antitrypsin deficiency without a significant smoking history.

To be included in the study, people who were healthy had to be sedentary. "Sedentary" was defined as "only performs activities with low metabolic cost, including light activities such as slow walking or cooking."[14(p174)] Exclusion criteria were regular participation in a formal exercise program during the 1-year period before the study; current smoking; and respiratory, cardiovascular, or neurological disease or lower-extremity musculoskeletal problems that could interfere with or could cause undue risk during the performance of a study test.

Thirty-eight people with COPD and 26 people who were healthy (control group) were recruited. Twenty-two people were excluded because they did not meet the criteria. The details of the recruitment process and the reasons for exclusion are shown in Figure 1. After exclusion, 21 non–oxygen-dependent, clinically stable people (11 men and 10 women)

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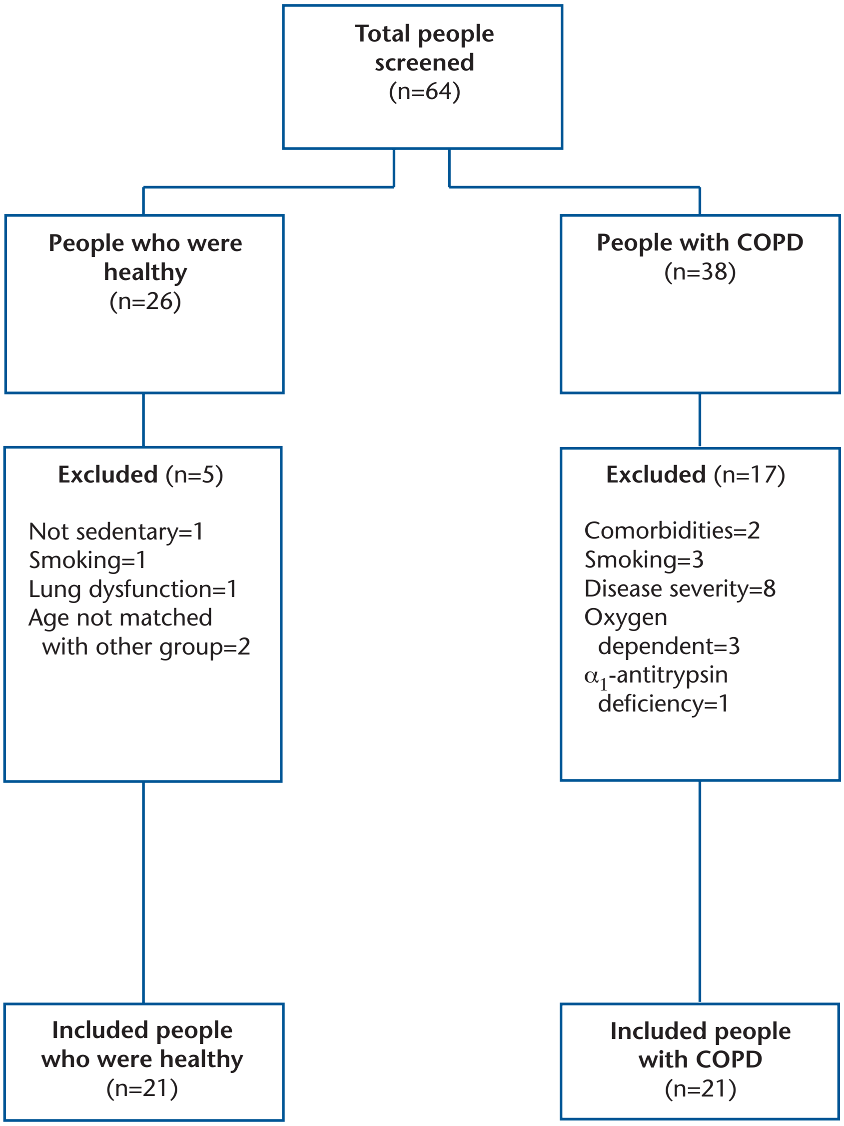

Figure 1.
CONSORT diagram showing the recruitment process and the reasons for exclusion. COPD=chronic obstructive pulmonary disease.

with moderate to severe COPD[12] and 21 people who were healthy but sedentary (control group) and matched for age, sex, and body mass were included in the study. The characteristics of the participants are shown in Table 1. People with COPD had moderate to severe levels of airflow limitation, which were confirmed by their lower values for spirometric measures in comparison with those of people who were healthy. All participants gave written informed consent before participation.

To estimate an appropriate sample size, standardized effect sizes anticipated from previous studies assessing strength deficits in people with COPD[6] were calculated by dividing the difference between the mean scores for the COPD and control groups by the pooled standard deviation.[15] Standardized effect sizes ranged from 0.8 to 1.2. Assuming a standardized effect size of 0.8, 80% power, and an α_2 level of .05, we estimated that at least 20 participants per group were needed to detect differences in muscle strength.[15]

Initial Screening

Before testing was begun, participants were asked to complete a risk screening questionnaire to guarantee their suitability for participation and to minimize any potential risk.[16] To confirm the severity of COPD and to rule out pulmonary disease, people with COPD and people who were healthy, respectively, underwent spirometry with a portable spirometer (CPFS/D spirometer*). Spirometry was performed in accordance with the guidelines of the American Thoracic Society and the European Respiratory Society.[17]

Measurements

SCPT. In the SCPT, the time required to climb a staircase of 10 stairs as quickly and safely as possible is recorded. In brief, participants were instructed to ascend the 10 stairs as quickly as they could. They were allowed to use the handrail only to increase their own safety; they were specifically instructed not to use the handrail to ascend the stairs faster. A more detailed description of the procedures of the SCPT is available elsewhere.[11] In brief, velocity is calculated by dividing the distance, which in this case is the total vertical height of the stairs, by the time required to climb the 10 stairs ($v=d/t$). Force is calculated by multiplying body weight by acceleration ($F=m \times a$); the latter is the constant for the effect of gravity (9.81 N). Thus, power ($P=F \times v$) for the SCPT is the product of (total vertical height of the stairs/time) × (body weight × 9.81).[11] Participants performed 2 trials of the SCPT, with at least 2 minutes of recovery between the trials. The same tester (M.R.) timed the SCPT manually with a stopwatch, and the trial with the

* Medical Graphics Corp, 350 Oak Grove Pkwy, St Paul, MN 55127-8507.

Table 1.
Characteristics of Study Participants[a]

Characteristic	Control Group (n=21)		COPD Group (n=21)	
	$\overline{X}$ (SD)	Range	$\overline{X}$ (SD)	Range
Age (y)	67.4 (8.6)	50–85	71.2 (8.1)	50–85
Height (m)	1.7 (0.1)	1.4–1.8	1.6 (0.1)	1.5–1.8
Weight (kg)	70.8 (14.6)	47–104	70.5 (14.2)	48.3–103.4
BMI (kg/m^2)	25.3 (4)	20–36	25.7 (4.2)	20.1–38.4
FEV_1 (% predicted)	98.1 (11.9)	76–114	47.2 (12.9)[b]	32–72
FVC (% predicted)	108 (20.6)	67–141	80.4 (15.9)[b]	42–102
FEV_1/FVC (% predicted)	69.5 (7.7)	57–85	52.4 (17.2)[b]	27–71

[a] COPD=chronic obstructive pulmonary disease, BMI=body mass index, FEV_1=forced expiratory volume in 1 second, FVC=forced vital capacity.
[b] Significant difference between groups at $P<.05$.

faster time was saved for further analysis.

Knee extensor and flexor muscle strength. The concentric and eccentric average peak torque of the knee extensor and flexor muscles of the dominant leg (determined by preference for kicking a ball) was assessed with a KinCom dynamometer (version 5.30).[†] In brief, participants were seated on the KinCom dynamometer with the knee joint aligned with the center of rotation of the dynamometer. The resistance pad was positioned distally at 75% of the distance from the lateral epicondyle to the lateral malleolus. Stabilizing belts were used to secure the pelvis and the upper body and to minimize extraneous movements. An angular velocity of 30°/s was chosen because it showed high reproducibility (intraclass correlation coefficient [ICC (2,1)]=.99) in a previous study of people with COPD.[18] The testing range of motion was set at 10 to 90 degrees and at 20 to 80 degrees of knee flexion for the knee extensor and flexor muscles, respectively. This range of motion was selected to diminish joint discomfort and force variability produced by the action of the hamstring muscles at the end of knee extension. After a warm-up consisting of 5 submaximal contractions, participants were asked to extend their knee as fast and as hard as they could. Knee flexor muscles were tested with the same procedures except that participants were asked to bend their knee. The same apparatus was used to assess the isometric knee extensor muscle average peak torque at 90 degrees of knee flexion. For this test, participants were asked to extend their knee as fast and as hard as they could and to maintain force production for 3 seconds. To ensure maximal effort, participants were vigorously encouraged. Three maximal trials for each muscle contraction and muscle group were recorded, with 2 minutes of recovery between the trials. Values from the 3 trials were averaged to obtain the peak torque.

Functional performance. Functional performance was assessed with the Timed "Up & Go" Test (TUG) and the Six-Minute Walk Test (6MWT). In brief, the TUG was performed by timing the ability to stand up from a chair, walk 3 m, cross a line marked on the floor, turn around, walk back to the chair, and sit down.[19] Participants performed 2 trials of the TUG, with 2 minutes of recovery between the trials. The same tester (M.R.) timed the TUG manually, and the trial with the faster time was saved for further analysis. The 6MWT was performed once according to the guidelines of the American Thoracic Society.[20] In brief, participants were instructed to walk as far as they could in 6 minutes in a 25-m hallway, and the distance walked was recorded. Mean peak oxygen uptake (peak $\dot{V}O_2$) values for each group were estimated from the 6MWT with the following equation[21]: $\text{mean peak } \dot{V}O_2 = 4.948 + 0.023 \times \text{mean 6MWT distance in meters}$.

Data Analysis

Assumptions of the normality of the data distribution for all variables were explored through histograms and normality plots.[22] Pearson or Spearman (for data not normally distributed) correlations were used to explore associations and multicollinearity among dependent variables and potential covariates. Collinear covariates showing weaker associations ($r<.5$) were eliminated. A regression model with age and body weight as covariates was used to determine differences between groups in all measures. The regression model was adjusted for age and body weight because these variables were independently correlated with measures

[†] Chattanooga Group Inc, 1430 Decision St, Vista, CA 92081.

Table 2.
Regression Model for Differences Between People With Chronic Obstructive Pulmonary Disease (COPD Group) and People Who Were Healthy (Control Group) on Various Measures[a]

Measure	Control Group (n=21)[b]	COPD Group (n=21)[b]	Mean Difference (95% Confidence Interval)	P
Stair Climb Power Test (W)	378.2 (121.3)	266.2 (80.3)	112.1 (74.2, 150)	<.001
Torque (N·m)				
Knee extensor muscle, concentric	80.3 (31.8)	55.7 (23.8)	24.6 (10.6, 38.6)	.001
Knee extensor muscle, eccentric	144.4 (50.9)	98.5 (29.2)	45.9 (25.8, 66.1)	<.001
Knee extensor muscle, isometric	74.8 (21.3)	100.2 (31.6)	25.3 (11, 39.7)	.001
Knee flexor muscle, concentric	37.8 (15.4)	28.4 (10.9)	9.5 (1.3, 17.6)	.024
Knee flexor muscle, eccentric	54.5 (19.7)	46.5 (17.1)	8 (−2, 18)	.114
Functional performance				
Timed "Up & Go" Test (s)	7.7 (1.1)	9.5 (2.3)	1.8 (0.7, 2.9)	.002
Six-Minute Walk Test (m)	554.9 (65)	394.6 (64.1)	160.2 (117.4, 203)	<.001

[a] The regression model was adjusted for age and body weight.
[b] Data are means (standard deviations).

of functional performance and muscle torque, respectively. Pearson product moment correlations were used to explore associations between the SCPT and measures of knee extensor muscle torque and functional performance. The strength of the correlations (*r*) was categorized as low (0–.25), moderate (>.25–.50), strong (>.50–.75), and very strong (>.75).[15] Test-retest reliability for all measures was calculated with ICCs (2,1).[15] Data are presented as means, standard deviations, and 95% confidence intervals. All analyses were performed using the Statistical Package for the Social Sciences[‡] with 2-tailed probability tests with the level of significance set at $P<.05$.

Role of the Funding Source

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[‡] SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.

Results

SCPT

The results of the regression model for the SCPT are shown in Table 2. All participants were able to perform the SCPT safely, and no adverse effects or unexpected events were reported. Compared with the control group, the COPD group developed, on average, 28% lower power during the SCPT. Test-retest reliability for the SCPT within the same session was very high (ICC [2,1]=.90).

Knee Extensor and Flexor Muscle Strength and Functional Performance

The results of the regression model for measures of muscle torque and functional performance are shown in Table 2. Compared with the control group, the COPD group showed significantly lower values for all torque measures (~32%), except for eccentric knee flexion, for which the difference was not statistically significant. In the COPD group, test-retest reliability for isometric knee extension torque (ICC [2,1]=.91) and for isokinetic knee extension and flexion torque (ICC [2,1]=.90–.97) was high. The control group showed similar reliability coefficients for isometric knee extension torque (ICC [2,1]=.90) and isokinetic knee extension and flexion torque (ICC [2,1]=.92–.96).

In the COPD group, performance on the TUG was significantly lower (23%). Test-retest reliability for the TUG within the same session was very high (ICC [2,1]=.95). The distance walked in the 6MWT was 28% lower in the COPD group than in the control group. The mean (SD) peak $\dot{V}O_2$ values were 13.9 (1.5) and 17.8 (1.5) mL/kg/min in the COPD and control groups, respectively. The mean difference between groups in peak $\dot{V}O_2$ values was 3.8 mL/kg/min (95% confidence interval=2.9–4.7) ($P<.001$).

Association Between the SCPT and Measures of Muscle Strength and Functional Performance

The Pearson correlation analysis confirmed that the SCPT was very strongly associated ($r\geq.66$, $P\leq.001$) with measures of knee extensor

Table 3.
Associations Between the Stair Climb Power Test and Various Measures of Muscle Torque in People Who Were Healthy (Control Group) and People With Chronic Obstructive Pulmonary Disease (COPD Group)[a]

Torque Measure	Pearson Correlation Coefficient, *r* (95% Confidence Interval), for:		
	Control Group (n=21)	COPD Group (n=21)	Both Groups
Knee extensor muscle, concentric	.81 (.58, .92)[a]	.41 (−.02, .72)	.74 (.56, .55)[a]
Knee extensor muscle, eccentric	.86 (.68, .94)[a]	.53 (.11, .79)[b]	.84 (.72, .91)[a]
Knee extensor muscle, isometric	.66 (.32, .85)[a]	.46 (.02, .75)[b]	.70 (.50, .83)[a]
Knee flexor muscle, concentric	.46 (.04, .74)[b]	.23 (−.24, .61)	.48 (.20, .69)[a]
Knee flexor muscle, eccentric	.61 (.24, .82)[a]	.47 (.03, .75)[b]	.57 (.32, .75)[a]

[a] Significantly associated at $P<.01$.
[b] Significantly associated at $P<.05$.

muscle concentric, eccentric, and isometric torque in the control group. Knee flexor muscle concentric torque ($r=.46$, $P<.03$) and eccentric torque ($r=.61$, $P=.003$) also showed moderate to strong associations with the SCPT in the control group. In contrast, associations between the SCPT and measures of torque in the COPD group tended to be more moderate and statistically significant only for eccentric ($r=.53$, $P=.015$) and isometric ($r=.46$, $P=.043$) knee extensor muscles and for eccentric knee flexor muscles ($r=.47$, $P=.043$). The associations between the SCPT and the various torque measures are shown in Table 3.

When the relationships between the SCPT and measures of functional performance were explored (Fig. 2), the Pearson correlation analysis revealed notable differences between groups. In the COPD group, the SCPT was strongly associated with the 6MWT ($r=.68$, $P=.001$) and moderately associated with the TUG ($r=-.46$, $P=.04$). In contrast, in the control group, there was no significant relationship between the SCPT and either the 6MWT ($r=.43$, $P=.052$) or the TUG ($r=.25$, $P=.28$) (Fig. 2).

Discussion

The main finding of this study was that compared with people who were healthy, people with moderate to severe COPD developed significantly lower power during the SCPT. Interestingly, although the SCPT was only moderately related to thigh muscle torque in the COPD group,

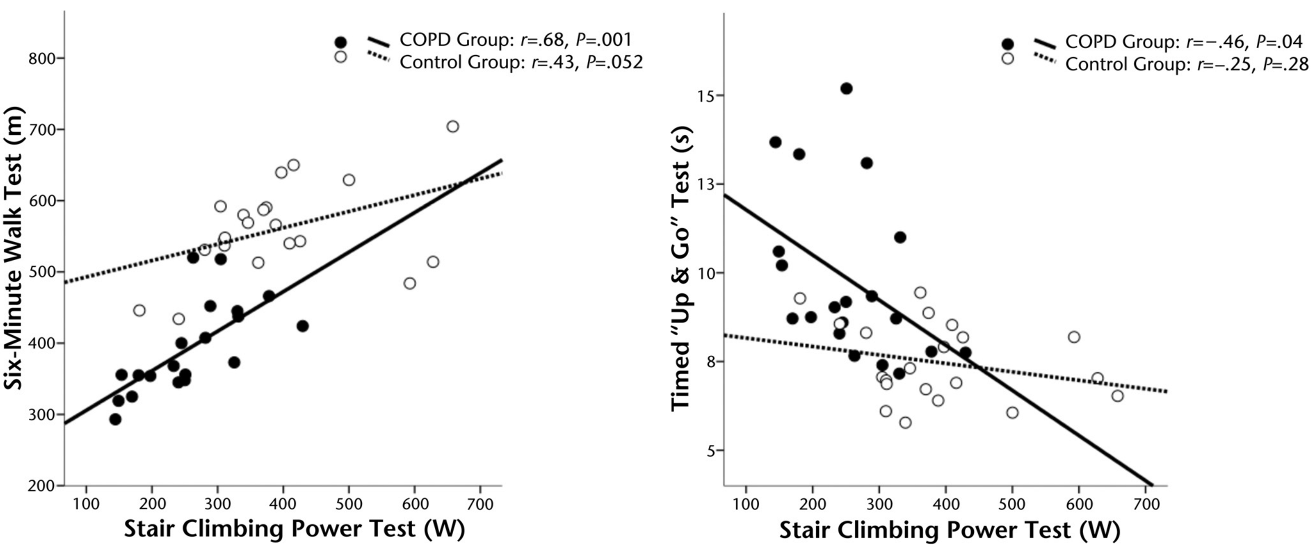

Figure 2.
Scatter plots showing associations of the Stair Climb Power Test with the Six-Minute Walk Test (left) and the Timed "Up & Go" Test (right) in people with chronic obstructive pulmonary disease (COPD group) (●) and people who were healthy (control group) (○). Regression lines with correlation coefficients for the COPD group (solid lines) and the control group (dashed lines) are shown.

this relationship was very strong in the control group. In contrast, although the SCPT was strongly to moderately related to the 6MWT and the TUG in the COPD group, weaker or nonsignificant relationships were found in the control group.

The lower power developed during the SCPT suggested that, like muscle strength,[6] leg muscle power is possibly impaired in people with COPD. However, we did not formally assess leg muscle power and thus cannot confirm that the SCPT is associated with more-mechanistic measures of muscle power in people with COPD. Because muscle power and muscle strength are closely related,[23] we hypothesized that the SCPT could be related to measures of knee extensor muscle torque in people with COPD. Of some surprise was the finding that knee extensor muscle torque in the COPD group was only moderately correlated with the SCPT, in contrast to the strong association in the control group. The high correlation of the SCPT with knee extensor muscle torque in the control group is consistent with the results of a previous report[11]; in that study, the SCPT was found to be associated ($r \geq .47$) with leg muscle power in older adults, as assessed with isotonic pneumatic machines. In contrast, the results of the present study indicated that the SCPT cannot be used as a surrogate for muscle strength in people with COPD.

The differences between groups in the relationships between muscle torque and the SCPT emphasized the importance of analyzing these unique relationships independently. A potential explanation for the different degrees of association between groups is that in people with COPD, factors other than muscle strength come into play during the SCPT. Indeed, our results indicated that during the performance of the SCPT, people with COPD were not able to develop powerful muscle contractions in accordance with their torque levels. Because stair climbing is a complex functional task that requires the coordinated integration of various body systems (ie, musculoskeletal, pulmonary, cardiovascular, and vestibular systems),[24] it is possible that other factors, such as ventilatory limitation, reduced postural control, or even fear of falling,[25] limited the performance of the SCPT in the COPD group. Perhaps the minimal effects of these limiting factors on participants in the control group enhanced the capacity to develop powerful muscle contractions that were more closely dependent on muscle strength.

The COPD group also showed significant deficits in functional performance, as assessed with the TUG and the 6MWT. These findings are consistent with the results of a previous study in which the investigators examined whether the TUG and the 6MWT were sensitive enough to discriminate between fallers and nonfallers in a group of people with COPD.[26] Compared with the results of the present study, however, the scores obtained in the TUG and the 6MWT in the fall risk study were approximately 25% lower. These results may have been due to the higher level of impairments in the participants in the latter study, as reflected in their lower mean (SD) percentage of forced expiratory volume in 1 second—predicted to be 41.5 (17)—and the use of supplemental oxygen in 46% of their participants. In general, our results are in line with those of other studies in which investigators, using similar mobility tests, reported deficits in functional performance in people with COPD compared with people who were healthy.[27–29]

We explored the similarities and differences between the SCPT and other functional tests, including the 6MWT and the TUG. In view of a recent report that showed no association between the time required to climb 44 stairs and the distance covered in the 6MWT in people with severe COPD (mean forced expiratory volume in 1 second=33 [SD=13]),[30] the strong association between the SCPT and the 6MWT in people with COPD was not expected. Indeed, although the short and intense muscle contractions elicited during the SCPT indicate that this test requires mainly the activation of anaerobic processes, the 6MWT has been traditionally used as the gold standard for the measurement of aerobic capacity.[31] A plausible explanation for the strong association between the SCPT and the 6MWT is that, because of the functional impairments in people with COPD, the 6MWT imposes a high physiological demand on them.[32] Indeed, a recent study confirmed that the same functional test (ie, the 6MWT) may provide different physiological information depending on the level of impairments in the participants.[33]

Although the scatter plot indicated a moderate relationship between the SCPT and the 6MWT (Fig. 2), no significant associations between the SCPT and measures of functional performance were found in the control group. At face value, these data may appear to conflict with those of a previous study,[33] which revealed a very strong inverse association ($r=-.83$) between the time to complete the SCPT and the distance covered in the 6MWT in older adults (mean age=72.7 years [SD=4.6]). An explanation for this disparity in findings is that power (which considers distance climbed and body weight), not the time to complete the SCPT, was calculated in the present study. When we correlated the time to complete the SCPT with the 6MWT in the control group, the association was similar to that reported in the previous study ($r=-.7$, $P<.001$).[33]

Another potential explanation for the weak associations of the SCPT with the 6MWT and the TUG in the control group is that the high levels of power developed during the SCPT in this group contributed only marginally toward the performance of these functional tests. For example, a recent study indicated that the capacity to produce muscle power at a high velocity and a lower resistance is more important than simply the magnitude of muscle power or strength during the performance of a walking task.[34] This finding is consistent with the analysis of outliers in our scatter plot (Fig. 2), which revealed that higher levels of power produced by 2 participants in the control group during the SCPT were not accompanied by greater distances walked during the 6MWT. Thus, the relationship between the SCPT and other measures of functional performance, such as the 6MWT, may not follow a linear pattern.[35] Instead, after a threshold of muscle power is achieved,[36,37] further improvements in muscle power may not translate to better functional performance.[38]

Limitations

The present study had some limitations. The most important limitations are the observational (cross-sectional) design of the study and the use of a convenience sample. Results from cross-sectional studies should be interpreted with caution because conclusions regarding cause and effect based on clinical correlates cannot be drawn.[15] Although our sample size estimation was appropriate for detecting significant differences between groups in most measures, the low correlations between some measures might have been related to the relatively small number of participants. In addition, the use of a convenience sample might have biased motivation for participation (ie, selection bias).

Conclusions

We explored the use of the SCPT, which is a functionally relevant test associated with leg muscle power in older adults.[11] People with COPD showed deficits on the SCPT, as well as on measures of muscle strength and functional performance. Although our results indicated that this test cannot be used as a simple surrogate for muscle strength, the SCPT is a simple, safe, and yet informative alternative for assessing functional performance in people with COPD. The clinical relevance of this test is that, although most functional tests used in people with COPD tend to focus on measures of aerobic capacity (eg, walking tests), the SCPT emphasizes the capacity to exert rapid contractions with the muscles of the lower limb. Detailed information regarding muscle power deficits in people with COPD is not yet available. Muscle power is particularly important in clinical evaluations because it is more closely related to functional performance,[39] postural control,[40,41] and possibly fall prevention strategies (eg, fast anticipatory movements)[42,43] than is muscle strength. Therefore, the SCPT may add some new clinical information to the characterization of functional impairments in people with COPD.

Larger studies assessing the nature of the relationships among measures of muscle strength, muscle power, and functional performance in people with COPD are needed. More studies assessing cardiorespiratory responses to the SCPT and the feasibility of this test for people with more severe COPD also are needed. In addition, the sensitivity and responsiveness of the SCPT for detecting functional improvements after training interventions should be explored.

Dr Roig, Dr Eng, Dr Road, and Dr Reid provided concept/idea/research design. Dr Roig, Dr Eng, and Dr Reid provided writing. Dr Roig and Dr MacIntyre provided data collection. Dr Roig and Dr Reid provided data analysis and project management. Dr Reid provided fund procurement and clerical support. Dr Roig and Dr Road provided participants. Dr MacIntyre and Dr Reid provided facilities/equipment. Dr Road and Dr Reid provided institutional liaisons. Dr MacIntyre, Dr Road, and Dr Reid provided consultation (including review of manuscript before submission). The authors thank Jennifer Rurak for editing a preliminary version of the manuscript.

The Clinical Research Ethics Board of the University of British Columbia approved the study.

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