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ORIGINAL ARTICLE

Cognitive and motor performances in dual task in patients with chronic obstructive pulmonary disease: a comparative study

Ismail Ozsoy[1] · **Gulsah Ozsoy**[1] · **Caner Kararti**[2] · **Buket Buyukturan**[2] · **Fidan Yilmaz**[2] · **Oznur Buyukturan**[2] · **Arzu Erturk**[3]

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Abstract

Background Patients with chronic obstructive pulmonary disease (COPD) may display a motor and/or cognitive disadvantage during dual tasking. However, studies investigating dual task are quite limited in patients with COPD.

Aims To compare cognitive and motor performances (i.e., muscle force production and functional balance/mobility together with a cognitive task) in dual task between patients with COPD and healthy controls.

Methods Thirty-five clinically stable patients with COPD and 27 age- and sex-matched healthy controls participated in this cross-sectional controlled study. The muscle force production (knee extension muscle strength assessed with an isokinetic strength dynamometer) and functional balance/mobility (Timed Up and Go (TUG) test) were performed with and without a cognitive task. Dual-task interference (DTI) was assessed. Additionally, the rate of correct responses per second (RCR) was calculated to evaluate cognitive performance.

Results The decrease in $RCR_{muscle\ force\ production}$ values was greater in the COPD group compared with the control group ($p = 0.045$). Similarly, the cognitive DTI in muscle force production test was higher in the control group than in the COPD group ($p < 0.001$). There was no significant difference in other outcome measures between the two groups ($p > 0.05$).

Conclusion The study results indicate that in individuals with COPD, cognitive performance deteriorations are more pronounced than motor performance defects during dual tasking. Further studies are needed to investigate the effects of dual task taking into account this disadvantage in patients with COPD rather than focusing solely on motor performance.

Keywords Chronic obstructive pulmonary disease · Cognitive performance · Dual task · Motor performance

Introduction

In daily life, we often have to do more than one task at a time such as walking while talking or thinking. This is referred to as dual task [1]. However, human capacity is very limited in successfully performing multiple tasks at the same time. Attention divided between two simultaneous tasks causes one or both tasks to fail, which is called dual-task interference (DTI) [2]. Frontal lobe dysfunction leading to associated decrease in attention capacity is thought to be the neurological background causing the DTI [3]. Higher levels of DTI due to frontal lobe dysfunction have been shown primarily in older people and in many neurological diseases [1, 4].

Central nervous system dysfunction is an extra-pulmonary complication in chronic obstructive pulmonary disease (COPD) [5]. Brain functions, especially frontal lobe functions, are shown to deteriorate as a result of COPD [6]. Studies have shown that the ability to perform complex multitask activities such as driving or walking together with a cognitive task is impaired in patients with COPD [7, 8]. It is also reported that the time to complete a functional test together with a cognitive task was prolonged in patients with COPD [9]. Moreover, this population is reported to have low muscle force production

✉ Ismail Ozsoy
ozsoy.ismail@yahoo.com

1 Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Selcuk University, Konya, Turkey

2 School of Physical Therapy and Rehabilitation, Kırsehir Ahi Evran University, Kırsehir, Turkey

3 Department of Chest Disease, Faculty of Medicine, Kırsehir Ahi Evran University, Kırsehir, Turkey

within the context of reduced motor cortex activity [10]. Although it is highly likely that patients with COPD would display a motor and/or cognitive disadvantage during muscle force production with a cognitive task, no study to date has investigated this subject. In addition, studies investigating functional balance in dual task are also quite limited in patients with COPD [9].

For many activities of daily living, it is very important for the patients with COPD to perform more than one task at the same time (such as maintaining balance together with a cognitive task). Any problem in performing one or both of the tasks can lead to serious health problems besides the inability in performing the whole activity [7]. In patients with COPD, successfully performing dual task is even more difficult as they generally have problems in maintaining balance alone [11]. Higher DTI during muscle force production and functional balance increases the risk of fall, disability, and mortality [12, 13]. Considering the fact that this is very likely in COPD, it is important to identify the task(s) that the patient has difficulty in. The aim of this study was to compare cognitive and motor performances (i.e., muscle force production and functional balance/mobility together with a cognitive task) in dual task between patients with COPD and healthy controls. We hypothesized that in the COPD group, the deterioration of both cognitive and motor performances during dual task would be worse than healthy controls.

Material and methods

Participants and study design

Thirty-five clinically stable patients with COPD and 27 age- and sex-matched healthy controls participated in this cross-sectional controlled study. The study was carried out between September 2019 and March 2020. A specialist (> 25 years of experience in COPD) made the diagnosis of COPD according to global initiative for chronic obstructive pulmonary disease (GOLD) guidelines and referred the patients to the pulmonary rehabilitation outpatient clinic of School of Physical Therapy and Rehabilitation, Kırsehir Ahi Evran University, Kırsehir, Turkey [14]. Minimum age of 18 years was set as one of the inclusion criteria. The study included patients with stable COPD who were on the same drug regimen over the past 3 weeks and were not taking antibiotics. Age- and sex-matched healthy controls who did not have any disease and health problems that would limit the tests were included. Social media announcements and brochures were used to recruit

Table 1 Characteristics of the participants

	COPD (n = 35)	Healthy (n = 27)	p
Age (years)	62.13 ± 8.17	60.60 ± 7.84	0.464[a]
Sex (men, %)	89.2	84.0	0.703[b]
BMI (kg/m^2)	27.95 ± 4.72	29.07 ± 3.25	0.308[a]
Smoking (pack-year)	40.74 ± 22.19	11.40 ± 12.54	*< 0.001*[a]
GOLD stage (I/II/III/IV)	3/25/7/2		
Pulmonary function test			
FEV_1 predicted (%)	59.18 ± 15.32		
FVC predicted (%)	76.16 ± 18.63		
FEV_1/FVC	60.89 ± 7.50		
Comorbidities			
Hypertension n (%)	20 (57.1)		
Diabetes mellitus n (%)	8 (22.8)		
Heart failure n (%)	6 (17.1)		
Other respiratory disease (asthma, obstructive sleep apnoea syndrome) n (%)	5 (14.2)		
Other comorbidities n (gastroesophageal disease, depression) (%)	3 (8.5)		
mMRC score (0–4)	1.81 ± 1.07		
CAT score (0–40)	16.13 ± 8.87		

[a] Independent samples t test

[b] Chi-square test.

Values are expressed as mean (standard deviation) for continuous variables and percent was reported for categorical variables. Italic values indicate significant p values (< 0.05)

Abbreviations: *BMI*, body mass index; *GOLD*, global initiative for chronic obstructive pulmonary disease; *FVC*, forced vital capacity; *FEV_1*, forced expiratory volume in 1 s; *mMRC*, modified medical research council; *CAT*, COPD assessment test

Table 2 Comparison of outcome measures

Outcome measures	COPD (n = 35)		p^1	Healthy (n = 27)		p^1	p^2	
	Single task	Dual task		Single task	Dual task		Condition	Group* condition
TUG test								
TUG time (s)	8.85 ± 2.05	10.94 ± 2.56	*< 0.001*	7.36 ± 1.69	9.34 ± 3.33	*< 0.001*	*< 0.001 (0.611)*	0.776 (0.001)
RCR_{TUG} (n s^{-1})	0.55 ± 0.39	0.25 ± 0.22	*< 0.001*	0.63 ± 0.38	0.37 ± 0.25	*< 0.001*	*< 0.001 (0.559)*	0.498 (0.008)
Muscle force production test								
PT/BW (%)	122.35 ± 44.04	98.28 ± 47.36	*< 0.001*	127.39 ± 44.02	107.96 ± 41.08	*0.006*	*< 0.001 (0.364)*	0.535 (0.006)
$RCR_{muscle\ force\ production}$ (n s^{-1})	0.37 ± 0.27	0.18 ± 0.18	*< 0.001*	0.56 ± 0.33	0.43 ± 0.30	*< 0.001*	*< 0.001 (0.602)*	*0.045 (0.066)*

Note: p^1, paired sample *t* test; p^2, two-way repeated measures analysis of variance. Values are expressed as mean ± standard deviation. Values in parentheses are effect sizes. Italic values indicate significant *p* values (< 0.05).

Abbreviations: TUG, timed up and go; *RCR*, rate of correct responses per second; *PT*, peak torque; *BW*, body weight

volunteering healthy controls. The exclusion criterion was the inability to perform motor and cognitive tasks due to a neurological, orthopedic, or cognitive problem. Written consent was obtained from all participants.

Data collection

Characteristics of the participants

Demographic and clinical characteristics of all participants were recorded. Pulmonary function was evaluated according to American Thoracic Society (ATS) and European Respiratory Society (ERS) guidelines using a spirometer (Quark- SPIRO spirometer, COSMED, Roma, Italy) [15]. Forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC), and FEV1/FVC values were recorded.

The Modified Medical Research Council (mMRC) Dyspnea Scale and the COPD Assessment Test (CAT) were used to assess dyspnea and health status, respectively [16, 17].

Measurements

To evaluate motor performance, muscle force production (i.e., knee extension muscle strength) and functional balance/mobility (i.e., Timed Up and Go test) were administered.

Muscle force production Knee extension muscle strength was measured using the Biodex System 4-Pro Isokinetic Strength Dynamometer®. During the test, the individuals were asked not to hold their breath or to distort their body posture. In order to prevent excessive movements, a thigh band, a trunk band, and a dorsal band were used to stabilize the thigh (without compressing the popliteal region), the trunk (to prevent forward bending), and the foot, respectively. Peak isokinetic concentric knee extension muscle force was tested at 60°/s angular velocity. Each participant performed 5 repetitions at 60°/s. Isokinetic muscle strength was calculated as peak torque (PT)/body weight (BW) ratios to eliminate individual body weight changes. It has been demonstrated that quadriceps muscle strength can be evaluated by an isokinetic protocol with one set of five repetitions at 60°/s [18].

Functional balance and mobility Timed up and Go (TUG) test was used to assess functional balance and mobility. The participants were asked to rise from a chair, walk 3 m, turn around, walk back to the chair, and sit down. TUG time was recorded in the single- and dual-task conditions to assess functional balance performance. Additionally, the TUG is shown to be valid and responsive in COPD [19].

Test procedure

Before the evaluations, the tests were explained to the participants. To minimize the methodological bias, all measurements were made by the same researcher and all participants were given the same instructions. In the dual-task condition, participants were instructed to perform the two tasks simultaneously (i.e., cognitive-motor dual task) without giving specific priority to any of the tasks. In order to avoid any potential problem caused by the same order of measurements, "Single-task" and "Double-task" measurements were performed in random orders.

The TUG test procedure

a) *Single motor task*: The TUG test was performed, and the time was recorded as an indicator of the motor performance of the participant.
b) *Single cognitive task*: Seated comfortably in a quiet room, the participant was asked to count down in intervals of 3, starting from 100. For each participant, the test duration was equal to his/her TUG test result. When the time was up, the total number of answers and the number of correct answers were recorded. As an indicator of cognitive performance, the rate of correct responses per second (RCR) was calculated using the formula below [7]:

$$\text{RCR} = (\text{Correct Answers}/\text{Total Time})*$$
$$(\text{Correct Answers}/\text{Total Answers})$$

c) *Dual task*: The participants were asked to perform the TUG test while counting down in intervals of 3, starting from 100. The time was recorded as an indicator of motor performance during dual task. On the other hand, the total number of answers and the number of correct answers were used to calculate RCR as an indicator of cognitive performance during dual task.

These three tests provided us with two values of motor performance (single- and dual-task TUG time), and two values of cognitive performance (single- and dual-task RCR). Using these values, motor and cognitive DTI values were calculated using the formulas below [2]:

$$\text{TUG DTI }(\%)\text{ Motor} = (\text{Dual Task TUG time} - \text{Single Task TUG time})/\text{Single Task TUG time}*100$$
$$\text{TUG DTI }(\%)\text{ Cognitive} = (\text{Dual Task RCR} - \text{Single Task RCR})/\text{Single Task RCR}*100$$

Muscle force production test procedure

a) *Single motor task*: Isokinetic muscle test was performed. PT/BW values were recorded as indicators of motor performance.
b) *Single cognitive task*: The test procedure was the same as described in the TUG test – single cognitive task. The test duration was equal to the participant's isokinetic test duration. For each participant, the total number of answers and the number of correct answers were recorded. The rate of correct responses per second (RCR) was calculated as described before.
c) *Dual task*: The participants were asked to perform the isokinetic muscle test while counting down in intervals of 3, starting from 100. The PT/BW was recorded as indicators of motor performance during dual task. On the other hand, the total number of answers and the number of correct answers were used to calculate RCR as an indicator of cognitive performance during dual task.

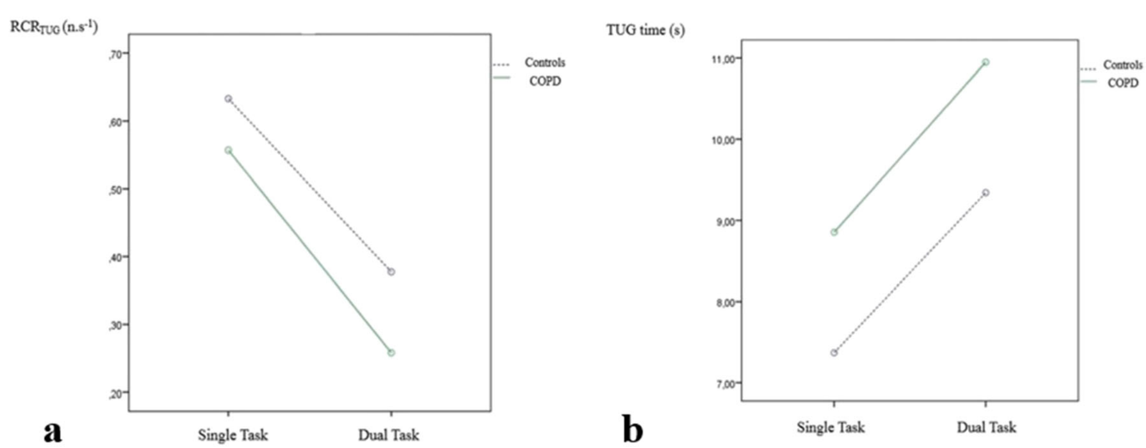

Fig. 1 a, b Comparison of TUG test between the two groups

These three tests provided us with two values of motor performance (single- and dual-task PT/BW), and two values of cognitive performance (single- and dual-task RCR). Using these values, motor and cognitive DTI values were calculated using the formulas below [2]:

$$\text{Muscle Force Production Test DTI } (\%) \text{ Motor} = (\text{Dual Task PT/BW} - \text{Single Task PT/BW})/\text{Single Task PT/BW}*100$$

$$\text{Muscle Force Production Test DTI } (\%) \text{ Cognitive} = (\text{Dual Task RCR} - \text{Single Task RCR})/\text{Single Task RCR}*100$$

Sample size

To the best of our knowledge, there is no study to evaluate muscle force production with a cognitive task in patients with COPD. However, a previous study showed that TUG time increased in dual task compared with single task in older individuals (dual-task TUG time = 29.7 ± 10.8 (s) and single-task TUG time = 22.2 ± 8.8 (s)) [20]. Based on these results, the minimum required sample size was calculated as 35 patients for the effect size of 0.568, the probability level as 0.05, the statistical power level as 90%, and using G*Power Software (ver. 3.1.9.2, Düsseldorf, Germany).

Data analysis

The IBM® SPSS® Statistics for Windows software (ver. 20.0; IBM Corp., NY, USA) was used to analyze the data. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Simirnov/Shapiro-Wilk's test) to determine whether or not the data were normally distributed. Values were expressed as mean ± standard deviation for continuous variables, and as number and frequencies for categorical variables. The Pearson correlation coefficient was calculated to examine the correlation between dual-task interference, disease severity, number of comorbidities, and smoking in the COPD group. The independent samples *t* test (for continuous variables) and the chi-squared test (for categorical variables) were used to compare the groups. To determine the mean difference between single and dual task, the paired sample *t* test was used. The two-way repeated measures analysis of variance was used to compare "condition" (single and dual task) and group* condition interaction between the COPD and control group. The classification of effect size (ηp^2) was determined by calculating partial eta square ($\eta p^2 = 0.0099$ (small effect), $\eta p^2 = 0.0588$ (medium effect), and $\eta p^2 = 0.1379$ (large effect)) [21].

Results

The data obtained from 35 patients with COPD (89.2% men) and 27 controls (84% men) were analyzed. There was no significant difference in demographic characteristics (age, sex, BMI) between the two groups ($p > 0.05$). The number of smokers was higher in the COPD group ($p < 0.001$) (Table 1). The demographic and clinic characteristics of the participants are presented in Table 1.

There was a statistically significant decrease in RCR_{TUG} values between single and dual task in both groups ($p < 0.001$, Table 2, Fig. 1a). Moreover, there was a statistically significant increase in TUG time between single and dual task in both groups ($p < 0.001$, Table 2, Fig. 1b). However, there was no statistically significant difference between the groups (group × condition interactions) regarding TUG time and RCR_{TUG} ($p > 0.05$, Table 2, Fig. 1).

There was a statistically significant decrease in PT/BW, and $RCR_{muscle\ force\ production}$ values between single and dual task in both groups ($p < 0.05$, Table 2, Fig. 2). There was no statistically significant difference between the groups (group × condition interactions) regarding PT/BW ($p > 0.05$,

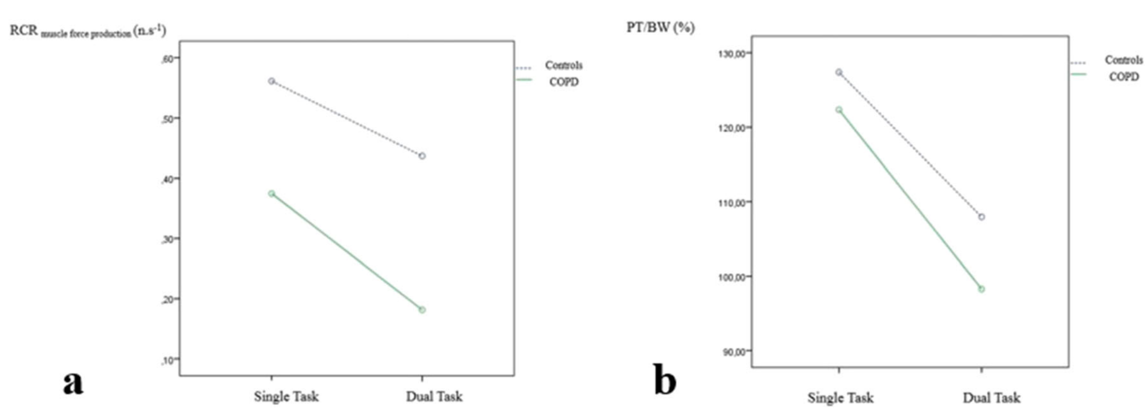

Fig. 2 a, b Comparison of muscle force production test between the two groups

Table 3 Comparison of dual-task interference

	COPD ($n = 35$)	Healthy ($n = 27$)	p
DTI TUG_{Motor} (%)	24.63 ± 17.07	24.88 ± 21.63	0.961
DTI $TUG_{Cognitive}$ (%)	49.33 ± 32.76	42.71 ± 24.68	0.394
DTI muscle force $production_{Motor}$ (%)	20.56 ± 22.87	9.07 ± 40.19	0.157
DTI muscle force $production_{Cognitive}$ (%)	63.22 ± 26.22	27.42 ± 26.37	*< 0.001*

Note: independent samples t test. Values are expressed as mean (standard deviation). Italic values indicate significant p values (< 0.05)

Abbreviations: *TUG*, timed up and go; *DTI*, dual-task interference

Table 2, Fig. 2). According to our findings, the decrease in $RCR_{muscle\ force\ production}$ values was greater in the COPD group compared with the control group ($p = 0.045$, Table 2, Fig. 2a).

There was no significant difference in cognitive and motor DTI in the TUG test between the two groups ($p > 0.05$, Table 3). Similarly, there was no significant difference in motor DTI in muscle force production test between the two groups ($p > 0.05$, Table 3). However, cognitive DTI in muscle force production test was higher in the control group than in the COPD group ($p < 0.001$, Table 3).

The predicted FEV_1 had a significant correlation with DTI muscle force $production_{Cognitive}$ ($r = -0.484$ and $p = 0.002$, Table 4). However, there was no correlation between the predicted FEV_1 and other DTI values ($p > 0.05$, Table 4). There was no correlation between the number of comorbidities and DTI values ($p > 0.05$, Table 4). Additionally, there was no correlation between smoking and DTI values ($p > 0.05$, Table 4).

Discussion

The main finding of the study indicated that the deterioration in cognitive performance during dual task (i.e., muscle force production together with a cognitive task) was more pronounced in patients with COPD than in healthy controls. Moreover, there was a significant correlation between disease severity and cognitive dual task interference (during muscle force production) in the COPD group. Surprisingly, alterations in motor performance during the same dual task condition were similar in both groups. Additionally, the cognitive and motor performances were comparable in the patients and controls in dual task of functional balance/mobility with a cognitive task.

The DTI is the result of the interaction between two simultaneously performed tasks. Therefore, to accurately interpret dual-task interference, both tasks must be assessed in single-task and dual-task conditions [2]. Unfortunately, studies on this subject mostly focus on motor performance in patients with COPD [9, 22]. Although cognitive dysfunction is a well-known consequence in patients with COPD [23], motor outcomes during dual task are given more importance [8]. However, prioritizing either motor or cognitive task while assessing dual tasking can lead to misleading results. For instance, although encouraging the participant to focus more on the motor task might yield more desirable motor outcome, yet it will push the simultaneously performed cognitive task into a backseat [2]. In the present study, however, motor and cognitive tasks were assessed both as single tasks and then as dual tasks given the same priority.

Attention divided into tasks performed at the same time causes one or both tasks to fail because of frontal lobe

Table 4 Correlation between dual-task interference, disease severity, number of comorbidities, and smoking in COPD group

	Disease severity (FEV_1 predicted (%))	Number of comorbidities (n)	Smoking (pack-year)
DTI TUG_{Motor} (%)	$r = -0.004$	$r = -0.015$	$r = 0.115$
	$p = 0.981$	$p = 0.929$	$p = 0.499$
DTI $TUG_{Cognitive}$ (%)	$r = -0.224$	$r = 0.146$	$r = 0.077$
	$p = 0.183$	$p = 0.389$	$p = 0.649$
DTI muscle force $production_{Motor}$ (%)	$r = -0.008$	$r = 0.297$	$r = 0.170$
	$p = 0.963$	$p = 0.074$	$p = 0.313$
DTI muscle force $production_{Cognitive}$ (%)	$r = -0.484$	$r = 0.296$	$r = 0.233$
	$p = 0.002$	$p = 0.076$	$p = 0.166$

Note: r = Pearson product moment correlation coefficient. Italic values indicate significant p values (< 0.05)

Abbreviations: *FEV_1*, forced expiratory volume in 1 s; *TUG*, timed up and go; *DTI*, dual-task interference dysfunction and the associated decrease in attention capacity [24]. Additionally, it is demonstrated that the ability to perform complex multitasking activities such as driving or walking while thinking is impaired in patients with COPD [7, 8] due to frontal lobe dysfunction [6]. Heraud et al. showed that although the impact on cognitive performance was comparable in patients with COPD and controls, motor performance was better in the controls during dual-task walking [7]. Additionally, two studies reported that patients with COPD had decreased performance in driving, which is a complex multitasking activity [8, 22]. To the best of our knowledge, no other studies have investigated motor and/or cognitive disadvantage during muscle force production with a cognitive task in patients with COPD, which makes comparisons more difficult. However, there are differences between our results and the results of studies that investigated dual tasking in individuals with COPD. Surprisingly, unlike previous studies in the literature, we found that alterations in motor performance during dual tasking (i.e., muscle force production together with a cognitive task) were similar in both groups whereas patients with COPD showed decreased cognitive performance. Additionally, there was a significant correlation between disease severity and cognitive dual task interference (during muscle force production) in the COPD group. These indicate that cognitive performance may be more negatively affected than motor performance during dual task in patients with COPD. One possible reason might be that other studies in the literature focus more on the motor task and the muscle strength tests are performed in non-balance-requiring positions. Further studies are needed on this subject.

The TUG test, which is a reliable test in patients with COPD [25], was used to assess functional balance and mobility. To the best of our knowledge, there is only one study in the literature in which TUG test is performed together with a cognitive task in patients with COPD. Morlino et al. investigated the impact of COPD on motor performance during dual-task TUG test. They asked the participants to count down in intervals of 3 while performing TUG. The researchers reported that the increase in the TUG time from single- to dual-task condition was significantly larger in patients with COPD than controls [9]. Contrary to this study, the TUG time was similar between the two groups in our study. To understand a possible reason for the difference between the results, it is important to highlight the methodological differences between these two studies. In the present study, we examined both the motor and cognitive performance during dual-task TUG test, whereas Morlino et al. studied only the motor performance in dual task TUG test [9]. It is also worth noting that although there was no difference in dual-task TUG time between the two groups in our study, the average TUG time in the COPD group increased from 8.85 to 10.94 s. According to Reynaud et al., the optimal diagnostic value for the TUG to detect a fall is 10.90 s with a sensitivity of 100% and a specificity of 97% [26]. Considering the fact that in our study dual tasking increased the TUG time above the cut-off value, it can be concluded that these individuals have an increased risk of falling.

Limitations

This study has some limitations that need to be addressed. First, although the number of participants was more than the minimum required sample size, the majority of them had a GOLD II classification. Therefore, study findings cannot be generalized to all patients with COPD with different disease severity. Second, the cross-sectional design of the study precludes inferences about the direction of causality among the variables.

Conclusion

The present study showed that alterations in motor performance during muscle force production together with a cognitive task was surprisingly similar in both groups, whereas the deterioration in cognitive performance in patients with COPD was worse compared with the healthy controls. Further studies should investigate the effects of dual task by taking into account this disadvantage in patients with COPD without focusing only on motor performance.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study protocol was approved by the local ethics committee (Report number: 2019-14/152).

Informed consent Informed consent was obtained from all participants included in the study.

References

1. Smith E, Cusack T, Cunningham C, Blake C (2017) The influence of a cognitive dual task on the gait parameters of healthy older adults: a systematic review and meta-analysis. J Aging Phys Act 25(4):671–686. https://doi.org/10.1123/japa.2016-0265
2. Plummer P, Eskes G (2015) Measuring treatment effects on dual-task performance: a framework for research and clinical practice. Front Hum Neurosci 9:225. https://doi.org/10.3389/fnhum.2015.00225
3. Al-Yahya E, Dawes H, Smith L et al (2011) Cognitive motor interference while walking: a systematic review and meta-analysis.

Neurosci Biobehav Rev 35(3):715–728. https://doi.org/10.1016/j.neubiorev.2010.08.008
4. Kahya M, Moon S, Ranchet M et al (2019) Brain activity during dual task gait and balance in aging and age-related neurodegenerative conditions: a systematic review. Exp Gerontol 128:110756. https://doi.org/10.1016/j.exger.2019.110756
5. Dodd JW, Getov SV, Jones PW (2010) Cognitive function in COPD. Eur Respir J 35(4):913–922. https://doi.org/10.1183/09031936.00125109
6. Borson S, Scanlan J, Friedman S et al (2008) Modeling the impact of COPD on the brain. Int J Chron Obstruct Pulmon Dis 3(3):429–434. https://doi.org/10.2147/copd.s2066
7. Heraud N, Alexandre F, Gueugnon M et al (2018) Impact of chronic obstructive pulmonary disease on cognitive and motor performances in dual-task walking. COPD 15(3):277–282. https://doi.org/10.1080/15412555.2018.1469607
8. Karakontaki F, Gennimata SA, Palamidas AF et al (2013) Driving-related neuropsychological performance in stable COPD patients. Pulm Med 2013:297371–297310. https://doi.org/10.1155/2013/297371
9. Morlino P, Balbi B, Guglielmetti S et al (2017) Gait abnormalities of COPD are not directly related to respiratory function. Gait Posture 58:352–357. https://doi.org/10.1016/j.gaitpost.2017.08.020
10. Alexandre F, Heraud N, Oliver N, Varray A (2014) Cortical implication in lower voluntary muscle force production in non-hypoxemic COPD patients. PloS One 9(6):e100961. https://doi.org/10.1371/journal.pone.0100961
11. Crişan AF, Oancea C, Timar B et al (2015) Balance impairment in patients with COPD. PloS One 10(3):e0120573. https://doi.org/10.1371/journal.pone.0120573
12. Kressig RW, Herrmann FR, Grandjean R et al (2008) Gait variability while dual-tasking: fall predictor in older inpatients? Aging Clin Exp Res 20(2):123–130. https://doi.org/10.1007/bf03324758
13. Tsang CSL, Pang MYC (2020) Association of subsequent falls with evidence of dual-task interference while walking in community-dwelling individuals after stroke. Clin Rehabil 34(7):971–980. https://doi.org/10.1177/0269215520923700
14. Singh D, Agusti A, Anzueto A et al (2019) Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease: the GOLD science committee report 2019. Eur Respir J 53(5):1900164. https://doi.org/10.1183/13993003.00164-2019
15. Graham BL, Steenbruggen I, Miller MR et al (2019) Standardization of spirometry 2019 update. An official American Thoracic Society and European Respiratory Society technical statement. Am J Respir Crit Care Med 200(8):e70–e88. https://doi.org/10.1164/rccm.201908-1590ST
16. Perez T, Burgel PR, Paillasseur JL et al (2015) Modified Medical Research Council scale vs Baseline Dyspnea Index to evaluate dyspnea in chronic obstructive pulmonary disease. Int J Chron Obstruct Pulmon Dis 10:1663–1672. https://doi.org/10.2147/copd.S82408
17. Karloh M, Fleig Mayer A, Maurici R et al (2016) The COPD Assessment Test: what do we know so far?: a systematic review and meta-analysis about clinical outcomes prediction and classification of patients into GOLD stages. Chest 149(2):413–425. https://doi.org/10.1378/chest.15-1752
18. Vieira L, Bottaro M, Celes R et al (2010) Isokinetic muscle evaluation of quadriceps in patients with chronic obstructive pulmonary disease. Rev Port Pneumol 16(5):717–736
19. Mesquita R, Wilke S, Smid DE et al (2016) Measurement properties of the Timed Up & Go test in patients with COPD. Chron Respir Dis. 13(4):344–352. https://doi.org/10.1177/1479972316647178
20. Cardon-Verbecq C, Loustau M, Guitard E et al (2017) Predicting falls with the cognitive timed up-and-go dual task in frail older patients. Ann Phys Rehabil Med 60(2):83–86. https://doi.org/10.1016/j.rehab.2016.07.003
21. Richardson JT (2011) Eta squared and partial eta squared as measures of effect size in educational research. Educ Res Rev 6(2):135–147. https://doi.org/10.1016/j.edurev.2010.12.001
22. Skovhus Prior T, Troelsen T, Hilberg O (2015) Driving performance in patients with chronic obstructive lung disease, interstitial lung disease and healthy controls: a crossover intervention study. BMJ Open Respir Res 2(1):e000092. https://doi.org/10.1136/bmjresp-2015-000092
23. van Beers M, Janssen DJA, Gosker HR, Schols AMWJ (2018) Cognitive impairment in chronic obstructive pulmonary disease: disease burden, determinants and possible future interventions. Expert Rev Respir Med 12(12):1061–1074. https://doi.org/10.1080/17476348.2018.1533405
24. Holtzer R, Stern Y, Rakitin BC (2005) Predicting age-related dual-task effects with individual differences on neuropsychological tests. Neuropsychology 19(1):18–27. https://doi.org/10.1037/0894-4105.19.1.18
25. Marques A, Cruz J, Quina S et al (2016) Reliability, agreement and minimal detectable change of the timed up & go and the 10-meter walk tests in older patients with COPD. COPD 13(3):279–287. https://doi.org/10.3109/15412555.2015.1079816
26. Reynaud V, Muti D, Pereira B et al (2019) A TUG value longer than 11 s predicts fall risk at 6-month in individuals with COPD. J Clin Med 8(10). https://doi.org/10.3390/jcm8101752