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► **To cite this version:**

Romain Pichon, Mathieu Ménard, Diane Haering, Armel Crétual, Marc Beaumont. Characteristics and Predictors of Postural Control Impairment in Patients With COPD Participating in a Pulmonary Rehabilitation Program. *Journal of Cardiopulmonary Rehabilitation and Prevention*, 2023, 10.1097/HCR.0000000000000762 . hal-04016371

HAL Id: hal-04016371

<https://hal.science/hal-04016371>

Submitted on 13 Mar 2023

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1 **Type of submission:** Original investigation

2 **Full title:** Characteristics and Predictors of Postural Control Impairment in Patients with
3 COPD participating in a Pulmonary Rehabilitation Program

4 **Short running title:** Predictors of Postural Control Impairment in COPD

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13 All authors meet the 4 ICMJE criteria for authorship, have read and approved the manuscript.

14

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18

19 **Keywords:** Chronic obstructive pulmonary disease, postural balance, pulmonary rehabilitation

20 **Sources of support:** none

21 **Conflicts of interest:** the authors report no conflict of interest

- 1 **Word count for the text-only portion of the manuscript: 2994**
- 2 **Numbers of tables: 2**
- 3 **Number of figures: 2**
- 4 **Number of references: 54**
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1 **Structured ABSTRACT**

2 Purpose: Postural control impairment has been identified as a potential extra-respiratory
3 manifestation in patients with COPD. The aims of this study were to identify clinical factors
4 that characterize patients with reduced postural control, to examine the correlation between
5 clinical factors and postural control and to determine predictors of an impaired postural control
6 among COPD participants enrolled in a pulmonary rehabilitation program.

7 Methods: This study is a secondary analysis of an observational study (PARACHUTE). The
8 baseline assessment of the pulmonary rehabilitation program was used for the analysis. The
9 postural control impairment was defined using the Brief-BESTest score (BBT).

10 Results: 73 participants were included in the analysis, 43 of them were classified in the reduced-
11 postural control group. The between-group comparison (non-reduced versus reduced postural
12 control) identified differences for partial pressure in oxygen (PaO_2), Saint-George respiratory
13 questionnaire (SGRQ) total score and sub-scores (SGRQ-Symptoms, SGRQ-Activities and
14 SGRQ-Impact), COPD assessment test (CAT) and anxiety score of Hospital Anxiety and
15 Depression scale. BBT score was significantly correlated with maximal inspiratory pressure
16 (MIP), SGRQ, SRGQ-Symptoms, SGRQ-Impact, Falls Efficacy Scale, modified Medical
17 Research Council scale, six-minute walk test and PaO_2 . Logistic regression identified SGRQ-
18 Symptoms, PaO_2 , MIP and body mass index (BMI) as predictors of the presence of a reduced
19 postural control.

20 Conclusion: Low quality-of-life (QoL) and PaO_2 and high anxiety seem to be discriminative
21 characteristics of COPD patients with reduced postural control. Furthermore, QoL, PaO_2 ,
22 inspiratory muscle strength and BMI seem to be acceptable predictors of the presence of a
23 postural control impairment.

24

1 **Condensed Abstract**

2 COPD patients with impaired postural control had a poorer QoL, lower PaO₂ and higher anxiety
3 scores compared to patients with normal postural control. Predictors of impaired postural
4 control in COPD patients were symptom-related QoL, PaO₂, inspiratory muscle strength and
5 body mass index.

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Key perspective
- The identification of discriminative and predictive parameters among classically assessed factors in pulmonary rehabilitation could help the detection of postural control impairment in COPD participants.
- Clinicians could use identified discriminative characteristics and / or clinical factors predictors to guide their clinical reasoning on postural control impairment in COPD patients.
- Future research is needed to investigate the effect of specific interventions aiming to modify identified predictors on postural control in COPD patients.

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1 Chronic Obstructive Pulmonary Disease (COPD) is a common, preventable and treatable
2 pathology that is characterized by persistent respiratory symptoms and airflow limitation.¹
3 According to the World Health Organization, COPD is the third highest cause of mortality
4 worldwide in 2019.² The evolution of COPD is not limited to respiratory symptoms:
5 comorbidities are extremely frequent during the evolution of the disease³, and increase the
6 impact on the quality of life of COPD patients.⁴ Among these comorbidities, the impairment of
7 postural control has been described as one important extra-respiratory manifestation for these
8 patients.⁵

9 Postural control is a complex system, which manages the body's position in space for the dual
10 purposes of stability and orientation.⁶ The postural control of COPD patients has been
11 documented by numerous experimental studies and three systematic reviews have highlighted
12 the impairment of postural control of people with COPD compared to control participants.⁷⁻⁹
13 However, the mechanisms behind and the potential consequences of postural control alteration
14 are only partially known.^{8,9}

15 Pulmonary rehabilitation is one of the major treatments for people with COPD¹⁰ and consists
16 of a comprehensive, individualised intervention based on thorough assessment of identifiable
17 treatable traits.^{11,12} Exercise training and therapeutic education are considered as cornerstones
18 of pulmonary rehabilitation and various interventions are delivered in addition to fit patient
19 needs.¹² The initial evaluation of a pulmonary rehabilitation program must be holistic to realize
20 an overview of patient's strengths, impairments, and project. To this purpose, a wide range of
21 areas are assessed during this evaluation (e.g. pulmonary function, symptoms, exercise
22 capacity, muscular function, quality of life, etc.).¹¹

23 The latest American Thoracic Society/European Respiratory Society statement on pulmonary
24 rehabilitation recommended to include the evaluation of postural control in the initial
25 assessment.¹³ However, no specific tests are recommended in the guidelines and a

1 comprehensive assessment of postural control can be complex, time-consuming, and is not
2 usually performed as a first-line procedure in patients with COPD.¹⁴ Although not all people
3 with COPD have impaired postural control (an estimated 40-45% have reduced postural
4 control^{15,16}), identifying the characteristics and predictors of a reduced postural control could
5 facilitate the detection and the classification of at risk-patients and thus individuals who require
6 a comprehensive postural control assessment. In addition, exploring the correlation between
7 postural control in COPD patients and various clinical factors could be of interest to clarify or
8 support hypotheses about the underlying mechanisms (e.g. muscle function or dyspnea⁹) and
9 impacts of postural control impairment (e.g. on activities of daily living or quality of life¹⁵).

10 The aims of this study were 1) to identify clinical factors that characterize patients with reduced
11 postural control, 2) to identify predictors of a reduced postural control in these patients and 3)
12 to investigate any correlation between postural control and clinical factors in patients with
13 COPD.

14

15 **METHODS**

16

17 ***STUDY DESIGN AND SETTINGS***

18 This study is a secondary cross-sectional analysis of the PARACHUTE study¹⁷, conducted in
19 the pulmonary rehabilitation unit of the Centre Hospitalier des Pays de Morlaix, from January
20 2019 to December 2019. This study's purpose was to determine the effect of a pulmonary
21 rehabilitation program on fear of falling of COPD patients. This research was approved by the
22 ethics committee of the Centre Hospitalier Universitaire de Brest (number 29BRC18.0246) and
23 was registered on Clinical Trials (number NCT03793452).

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PARTICIPANTS

Inclusion criteria were as follows: patients older than 18 years old with a confirmed diagnostic of COPD stage 2 to 4 (A-D) according to the GOLD criteria.¹

Exclusion criteria were: (1) Patients with a diagnosed pathology impairing his balance, (2) Previous pneumonectomy or lobectomy in the past 6 months, (3) Refusal of participation, (4) Patients with an incapacity to follow a standard rehabilitation program, (5) Pregnant or breast-feeding woman, (6) Patients under tutorship or curatorship.

Participants participated on a four-week program in the pulmonary rehabilitation unit of the Centre Hospitalier des Pays de Morlaix. Patients were assessed at the beginning and at the end of the program. The study of the association between postural control and clinical factors was performed on baseline data.

ASSESSMENTS

The postural control was assessed using the Brief BESTest (BBT) which is a composite functional tool¹⁸. The BBT is a derivative of the BESTest, an assessment aiming to investigate every sub-components of postural control.^{19,20} The BBT explores a significant number of sub-components of postural control (seven out of nine according to Sibley et al. operational definition of postural control²¹). The BBT is valid²² and reliable^{22,23} in the COPD population. Normative values were reported by O'Hoski et al.²⁴ for people from 50 to 90 years old.

Every participant realized a spirometry with Forced Expiratory Volume in 1 second and Forced Vital Capacity maneuvers after bronchodilators, in accordance to international recommendations.²⁵

1 An arterial puncture was performed for arterial blood gases analysis to obtain the resting partial
2 pressure of oxygen in blood (PaO₂) and the partial pressure of carbon dioxide in blood.

3 Inspiratory muscle strength was obtained by assessing the maximal inspiratory pressure (MIP)
4 measured using a Micro RPM (Micro Medical), following the European Respiratory Society
5 statement on respiratory muscle testing.²⁶ Isometric maximal voluntary quadriceps strength and
6 quadriceps endurance were measured using a hand-held dynamometer (MicroFET 2, Hoggan),
7 following a standardized, validated and reliable procedure.^{27,28}

8 Exercise capacity was measured using the six-minute walk test and the one-minute Sit to Stand
9 test. The six-minute walk test is a self-paced walking test, which measures the distance covered
10 by an individual over the course of six minutes. This is a valid and reliable tool for assessing
11 exercise capacity in people with COPD.²⁹ The one-minute Sit to Stand test assessed the ability
12 to change from a sitting to a standing position repeatedly, for one minute. The one-minute Sit
13 to Stand test is a relevant and reliable tool for assessing functional status of patients with
14 COPD.³⁰

15 Dyspnea was evaluated in a multi-dimensional way with the Dyspnea-12 questionnaire, the
16 Modified Medical Research Council dyspnea Scale, the London Chest Activity of Daily Living
17 and the Multidimensional Dyspnea Profile (conducted at the end of the six-minute walk test).
18 The Dyspnea-12 is a questionnaire investigating the affective and sensory dimensions of the
19 dyspnea.³¹ The Modified Medical Research Council is a zero-to-four scale, assessing the global
20 impact of dyspnea in the life of patients.³² The London Chest Activity of Daily Living is a tool
21 designed to assess the impact of dyspnea in fifteen different activities of daily living.³³ The
22 Multidimensional Dyspnea Profile is a composite tool that assessed the affective and sensory
23 dimension of dyspnea related to an activity.³⁴ The Multidimensional Dyspnea Profile is
24 separated into three different scales (“A1” and “A2” regarding affective dimension of dyspnea

1 and “QS” regarding the sensory dimension of dyspnea). These questionnaires were validated in
2 the COPD population and translated into French.^{35,36}

3 Quality of life (QoL) was measured with both the Saint George Respiratory questionnaire
4 (SGRQ) and the COPD Assessment Test (CAT). The SGRQ is a questionnaire designed to
5 measure the impact on overall health, daily life, and perceived well-being in patients with
6 obstructive airways disease.³⁵ The SGRQ gives three sub-scores (symptoms, activities, and
7 impacts) and a total score. Each score is given on a 0-to-100-point scale (a higher score indicates
8 a higher impact of the disease in the QoL of patients). The CAT is a questionnaire assessing the
9 impact of COPD on health status.³⁸ The CAT totals eight items, each item is scored on a 1 to 5
10 point scale. Range of CAT scores from 0–40 where higher scores denote a more severe impact
11 of COPD on patient life.

12 Anxiety and depression were evaluated using the Hospital Anxiety and Depression Scale .³⁹ It
13 consists of 14 items, 7 for anxiety disorders and 7 for depressive disorders. Each item is scored
14 between 0 and 3 and a score out of 21 is given for each dimension. A higher score indicates a
15 higher risk of anxiety or depressive symptoms.

16 Patients were asked to report falls on the twelve-month period before the inclusion in the
17 program. Fear of falling was evaluated using the Fall Efficacy Scale-International.⁴⁰ , a self-
18 administered questionnaire designed to assess the fear of falling that has been widely used in
19 previous research in the COPD population.^{41,42} It consists of 16 items, scored from 1 to 4 by the
20 patient. The total score is therefore between 16 and 64 points. A high score indicates a high fear
21 of falling.

22

23 ***STATISTICAL ANALYSIS***

1 Descriptive data were presented as mean (\pm standard deviation) or as median (interquartile
2 range) according to the nature of the variable and the distribution. The normality of the
3 distribution was tested using the Shapiro-Wilk test.

4 Using the normative values of the BBT ²⁴, a reduction of postural control was defined by a BBT
5 score below the lower limit of the 95% confidence interval to the mean BBT score for the
6 decade. Thus, the participants were classified into the reduced postural control group or the
7 non-reduced postural control group. The analysis of the differences between these two groups
8 was performed using the independent Student t-test, the Mann-Whitney U test or the χ^2 . The
9 effect size for between-group differences was calculated using the Cohen's *d* or the rank biserial
10 correlation.

11 The correlation analysis between the postural control score (BBT) and the clinical factors was
12 performed using the Pearson correlation coefficient or the Spearman's rank correlation
13 coefficient.

14 A binomial logistic regression was performed with the presence or not of a reduced postural
15 control as the dependent variable. A forward stepwise approach was used to determine the best
16 regression model. Independent variables were selected from the between-groups analysis and
17 the correlation analysis. The number of independent variables selected was adapted to the
18 sample size, using the rule of thumb of a minimum of ten participants per predictor.⁴³ Selected
19 independent variables were successively incorporated into the model to obtain the lowest
20 possible Akaike Information Criterion and the higher possible Nagelneke R^2 . A Receiver
21 Operating Characteristic curve was performed to evaluate the sensitivity and the specificity of
22 the regression model.

23 A p-value of less than 0.05 was considered statistically significant. The statistical analysis was
24 performed using Jamovi 1.8.1.0 (The Jamovi Project).

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RESULTS

PARTICIPANTS AND CHARACTERISTICS

80 patients were consecutively included in the PARACHUTE study. Seven patients were excluded from the final analysis: four participants did not respect eligibility criteria and three did not perform the postural control assessment at baseline. Thus, a total of 73 participants were included in the analysis. The detailed characteristics of included patients are shown in the *table 1*. 43 participants presented a reduced postural control as previously defined in study's methods, 26 participants were considered having a non-reduced postural control and four participants were not classified (no normative data available for their age decade). The between group comparison (reduced postural control versus non-reduced postural control) showed significant differences in the following clinical factors: PaO₂ ($P = .019$; $d = .62$), SGRQ-total ($P = .04$; $d = -0.75$), SGRQ-Symptoms ($p < .001$; $d = -0.88$), SGRQ-Activities ($P = .02$; $d = -0.59$), SGRQ-Impacts ($P = .045$; $d = -0.51$), CAT ($P = .040$; $d = -0.52$) and Anxiety score of Hospital Anxiety and Depression Scale ($P = .015$; $d = -0.63$). The difference was not significant for BMI ($P = .07$; $d = -0.45$) and MIP ($P = .09$; $d = .42$).

CORRELATIONS

The significant correlations between postural control (BBT score) and the clinical factors are represented in the *table 2*. This analysis was performed for all participants, independently of postural control status.

1 **LOGISTIC REGRESSION**

2 The logistic regression was performed to determine predictive factors for presenting a reduced
 3 postural control. The best logistic regression model included the SGRQ-Symptoms (OR =1.05:
 4 95% CI, 1.02 - 1.08, $P = .003$), PaO₂ (OR = .93: 95% CI, .87 - .99, $P = .020$), MIP (OR = .96:
 5 95% CI, .93 - .99, $P = .020$) and BMI (OR =1.15: 95% CI, 1.01 - 1.31, $P = .034$). This model
 6 was the best in accordance with the *a priori* set criteria (Akaike Information Criterion = 69.6;
 7 Nagelneke $R^2 = .44$). Setting the cut-off at 0.67, the model sensibility was 74% and specificity
 8 was 74%, the area under the curve was 0.84 (*figure 1*).

9 The final equation is the following:

$$10 \quad \mathbf{P \text{ (Reduced postural control)}} = 2.4201 + 0.0481*\text{SGRQ-Symptoms} - 0.0771*\text{PaO}_2 -$$

$$11 \quad 0.0390*\text{MIP} + 0.1418*\text{BMI}$$

12 Where “P (reduced postural control)” is the probability of presenting a reduced postural control.

13 The estimated marginal means for each predictor are represented in the *figure 2*.

14

15 **DISCUSSION**

16

17 The main aim of this study was to identify clinical factors that characterized COPD patients
 18 with reduced postural control: these patients presented significantly impaired QoL scores, lower
 19 PaO₂ and higher anxiety score. Secondly, the analysis of the correlation between postural
 20 control and clinical factors identified significant associations with QoL, PaO₂, inspiratory
 21 muscle strength, dyspnea, exercise capacity and fear of falling. Lastly, predictive clinical factors

1 of an impaired postural control were symptom-related QoL, PaO₂, inspiratory muscle strength
2 and BMI.

3 Previous research has shown that postural control impairment is frequent in COPD patients.^{15,16}

4 In the present study, nearly six out of ten COPD patients were considered to have a reduced
5 postural control. So, this study adds to the evidence that postural control impairment is very
6 common in patients with COPD, and that this domain must be explored by clinicians with
7 regard to its consequences in terms of falling⁴⁴ and performing daily tasks¹⁵.

8 This study identified that the QoL is significantly more impaired in COPD patients with altered
9 postural control. QoL scores were also correlated with postural control, and the symptoms sub-
10 score of the SGRQ was identified as the strongest predictor of the presence of a reduced postural
11 control in these patients. The reduction of QoL in patients with impaired postural control and
12 the significant correlation could suggest that postural control impairment has a negative impact
13 on daily lives of people with COPD. However, the identification of the SGRQ-symptoms sub-
14 score as one of the predictors of a reduced postural control could implicate that the relation
15 between these parameters is bilateral: on the one hand, it seems probable that a reduction in
16 postural control induces an impairment in quality of life. But on the other hand, symptoms (such
17 as dyspnea) and their perceived consequences have the potential to interact negatively with
18 postural control, as suggested by previous research⁹.

19 If some authors have hypothesized that hypoxemia could be an underlying mechanism of
20 postural control impairment in COPD⁴⁵, few studies on postural control included a direct
21 measure of arterial blood pressure in oxygen. Ozalevli et al.⁴⁶ reported a significant correlation
22 between PaO₂ and the Berg balance scale ($r = .28$) in patients with COPD, which is in line with
23 the present study. According to our results, the PaO₂ is also a significant predictor of the
24 presence of a reduced postural control in COPD patients: any decrease in PaO₂ increases the
25 risk of presenting a postural control impairment in the latter.

1 The results of this study suggest that inspiratory muscle strength could play a role in postural
2 control impairment in COPD. The presence of a reduced inspiratory strength could increase the
3 risk of presenting a postural control impairment in COPD patients. This is in line with previous
4 clinical research⁴⁷ and is consistent with laboratory studies that highlighted the role of
5 inspiratory muscles in postural control function^{48,49}. This finding is potentially important for
6 the management of COPD patients with decreased postural control function, as inspiratory
7 muscle training could be a relevant intervention for them. While balance training or functional
8 exercises are the interventions with the highest level of evidence^{50,51}, previous studies in
9 elderly⁵² and in people with COPD⁵³ have shown that inspiratory muscle training could be a
10 potential relevant intervention for postural control enhancement

11 Our results identified that the BMI is a significant predictor of postural control impairment in
12 patients with COPD: in our analysis any raise in the BMI increases the risk of presenting a
13 reduced postural control. Using a similar study design, Jacome et al. reported BMI as a
14 significant predictor of reduced postural control with comparable odds ratio (OR =1.12 in
15 Jacome study versus 1.16 here).¹⁶

16 Previous studies attempted to identify predictors of reduced postural control in COPD patients:
17 Jacome et al.¹⁶ identified BMI, number of medications, alterations in recreational activities and
18 depression score as predictors of reduced postural control (defined by a Timed up and Go score
19 below normative values). Liwsrisakun et al.⁵⁴ found that the exercise capacity (assessed by the
20 six-minute walk test) was the only predictor of a reduced postural control (here defined using
21 fall risk cut-off for the Timed up and Go test and the Berg Balance Scale). The definition of
22 “reduced postural control” differed in these studies and the clinical factors used for logistic
23 regression were not the same and could therefore explain the differences observed.

24 Even if identified predictors are the result of a statistical analysis, it could be hypothesized that
25 positive changes in these predictor scores could induce interesting modifications in postural

1 control of COPD patients. Future studies should investigate the impact on postural control of
2 changes in QoL, PaO₂, inspiratory muscle strength or BMI.

3

4 ***LIMITATIONS***

5 Firstly, this is a secondary analysis of a study designed for a different purpose. It implicates that
6 the sample size calculation was not tailor made for this purpose and that the number of included
7 participants is small for this type of analysis. However, for logistic regression analysis, some
8 authors suggested a sample size of ten participants per predictor,⁴³ which is the case here. In
9 any case, the equation needs to be validated with a larger sample size and confirmed
10 prospectively. The second limitation is that participants were voluntary patients participating in
11 a pulmonary rehabilitation program. This does not represent all patients with COPD and the
12 extrapolation to the whole COPD population should be confirmed in future research with a
13 more representative panel.

14

15 **CONCLUSION**

16 In the context of a pulmonary rehabilitation program, this study shows that COPD patients with
17 reduced postural control present characteristics in several clinical factors that distinguish them
18 from patients with non-impaired postural control. Symptom-related QoL, PaO₂, MIP and BMI
19 were identified as predictors of an impaired postural control in these patients.

20

21

22 **Acknowledgement:** the authors would like to thank Dr.Karim Jamal for his expert input on
23 postural control and Beverly McClure and John Kerr for their help in the proofreading and

1 correcting the language of the manuscript. The authors would also like to thank Dr.Catherine
2 Le Ber, Loic Péran and Anne-Cécile Berriet from the pulmonary rehabilitation unit of the
3 Centre Hospitalier des Pays de Morlaix for the work on the princeps study and the active
4 collaboration on the present study.

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1 REFERENCES

- 2 1. Global Initiative for Chronic Obstructive Lung Disease. *Global Strategy for the Diagnosis,*
3 *Management, and Prevention of COPD, 2020 Report.*; 2020.
- 4 2. World Health Organization. Global health estimates: Leading causes of death.
5 www.who.int. 2020.
- 6 3. Putcha N, Drummond MB, Wise RA, Hansel NN. Comorbidities and Chronic
7 Obstructive Pulmonary Disease: Prevalence, Influence on Outcomes, and Management.
8 *Semin Respir Crit Care Med.* 2015;36(4):575-591.
- 9 4. Huber MB, Wacker ME, Vogelmeier CF, Leidl R. Comorbid Influences on Generic
10 Health-Related Quality of Life in COPD: A Systematic Review. *PloS One.*
11 2015;10(7):e0132670. doi:10.1371/journal.pone.0132670
- 12 5. Roig M, Eng JJ, MacIntyre DL, Road JD, Reid WD. Postural Control Is Impaired in
13 People with COPD: An Observational Study. *Physiother Can.* 2011;63(4):423-431.
- 14 6. Shumway-Cook A, Woollacott MH. *Motor Control: Translating Research into Clinical*
15 *Practice.* Lippincott Williams & Wilkins; 2007.
- 16 7. Porto E, Castro A, Schmidt V, et al. Postural control in chronic obstructive pulmonary
17 disease: a systematic review. *Int J Chron Obstruct Pulmon Dis.* 2015;10:1233-1239.
18 doi:10.2147/COPD.S63955
- 19 8. Chuatrakoon B, Ngai SPC, Sungkarat S, Uthaikeup S. Balance Impairment and
20 Effectiveness of Exercise Intervention in Chronic Obstructive Pulmonary Disease-A
21 Systematic Review. *Arch Phys Med Rehabil.* 2020;101(9):1590-1602.

- 1 9. Loughran KJ, Atkinson G, Beauchamp MK, et al. Balance impairment in individuals
2 with COPD: a systematic review with meta-analysis. *Thorax*. 2020;75(7):539-546.
- 3 10. McCarthy B, Casey D, Devane D, Murphy K, Murphy E, Lacasse Y. Pulmonary
4 rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev*.
5 2015;(2):CD003793. doi:10.1002/14651858.CD003793.pub3
- 6 11. Spruit MA, Singh SJ, Garvey C, et al. An official American Thoracic Society/European
7 Respiratory Society statement: key concepts and advances in pulmonary rehabilitation.
8 *Am J Respir Crit Care Med*. 2013;188(8):e13-64.
- 9 12. Wouters EFM, Wouters BBREF, Augustin IML, Houben-Wilke S, Vanfleteren LEGW,
10 Franssen FME. Personalised pulmonary rehabilitation in COPD. *Eur Respir Rev Off J*
11 *Eur Respir Soc*. 2018;27(147):170125.
- 12 13. Garvey C, Bayles MP, Hamm LF, et al. Pulmonary Rehabilitation Exercise Prescription
13 in Chronic Obstructive Pulmonary Disease: Review of Selected Guidelines. *J*
14 *Cardiopulm Rehabil Prev*. 2016;36(2):75-83.
- 15 14. Beauchamp MK. Balance assessment in people with COPD: An evidence-based guide.
16 *Chron Respir Dis*. 2018;16:1479973118820311.
- 17 15. Cruz J, Marques A, Jácome C, Gabriel R, Figueiredo D. Global Functioning of COPD
18 Patients With and Without Functional Balance Impairment: An Exploratory Analysis
19 Based on the ICF Framework. *COPD*. 2015;12(2):207-216.
20 doi:10.3109/15412555.2014.933793

- 1 16. Jácome C, Cruz J, Gabriel R, Figueiredo D, Marques A. Functional balance in older
2 adults with chronic obstructive pulmonary disease. *J Aging Phys Act.* 2014;22(3):357-
3 363.
- 4 17. Berriet AC, Beaumont M, Peran L, Le Ber C, Couturaud F. Effects of pulmonary
5 rehabilitation on fear of falling in Chronic Obstructive Pulmonary Disease(COPD)
6 patients: an observational study. *Respir Med Res.* Published online June 12,
7 2022:100932. doi:10.1016/j.resmer.2022.100932
- 8 18. Padgett PK, Jacobs JV, Kasser SL. Is the BESTest at its best? A suggested brief version
9 based on interrater reliability, validity, internal consistency, and theoretical construct.
10 *Phys Ther.* 2012;92(9):1197-1207.
- 11 19. Horak FB. Postural orientation and equilibrium: what do we need to know about neural
12 control of balance to prevent falls? *Age Ageing.* 2006;35 Suppl 2:ii7-ii11.
- 13 20. Horak F, Wrisley D, Frank J. The Balance Evaluation Systems Test (BESTest) to
14 Differentiate Balance Deficits. *Phys Ther.* 2009;89:484-498.
- 15 21. Sibley KM, Beauchamp MK, Van Ooteghem K, Straus SE, Jaglal SB. Using the systems
16 framework for postural control to analyze the components of balance evaluated in
17 standardized balance measures: a scoping review. *Arch Phys Med Rehabil.*
18 2015;96(1):122-132.e29.
- 19 22. Jácome C, Cruz J, Oliveira A, Marques A. Validity, Reliability, and Ability to Identify
20 Fall Status of the Berg Balance Scale, BESTest, Mini-BESTest, and Brief-BESTest in
21 Patients With COPD. *Phys Ther.* 2016;96(11):1807-1815.

- 1 23. Leung RWM, Alison JA, McKeough ZJ. Inter-rater and intra-rater reliability of the
2 Brief-BESTest in people with chronic obstructive pulmonary disease. *Clin Rehabil.*
3 2019;33(1):104-112.
- 4 24. O'Hoski S, Winship B, Herridge L, et al. Increasing the Clinical Utility of the BESTest,
5 Mini-BESTest, and Brief-BESTest: Normative Values in Canadian Adults Who Are
6 Healthy and Aged 50 Years or Older. *Phys Ther.* 2014;94(3):334-342.
- 7 25. Graham BL, Steenbruggen I, Miller MR, et al. Standardization of Spirometry 2019
8 Update. An Official American Thoracic Society and European Respiratory Society
9 Technical Statement. *Am J Respir Crit Care Med.* 2019;200(8):e70-e88.
- 10 26. Laveneziana P, Albuquerque A, Aliverti A, et al. ERS statement on respiratory muscle
11 testing at rest and during exercise. *Eur Respir J.* 2019;53(6).
- 12 27. Bachasson D, Villiot-Danger E, Verges S, et al. [Maximal isometric voluntary
13 quadriceps strength assessment in COPD]. *Rev Mal Respir.* 2014;31(8):765-770.
14 doi:10.1016/j.rmr.2013.10.645
- 15 28. Beaumont M, Kerautret G, Peran L, Pichon R, Le Ber C, Cabillic M. [Reproducibility of
16 strength and endurance measurements of the quadriceps in patients with COPD]. *Rev*
17 *Mal Respir.* 2017;34(9):1000-1006.
- 18 29. Bui KL, Nyberg A, Maltais F, Saey D. Functional Tests in Chronic Obstructive
19 Pulmonary Disease, Part 2: Measurement Properties. *Ann Am Thorac Soc.*
20 2017;14(5):785-794.
- 21 30. Vaidya T, Chambellan A, de Bisschop C. Sit-to-stand tests for COPD: A literature
22 review. *Respir Med.* 2017;128:70-77.

- 1 31. Yorke J, Moosavi SH, Shuldham C, Jones PW. Quantification of dyspnoea using
2 descriptors: development and initial testing of the Dyspnoea-12. *Thorax*. 2010;65(1):21-
3 26.
- 4 32. Mahler DA, Wells CK. Evaluation of clinical methods for rating dyspnea. *Chest*.
5 1988;93(3):580-586.
- 6 33. Garrod R, Bestall JC, Paul EA, Wedzicha JA, Jones PW. Development and validation of
7 a standardized measure of activity of daily living in patients with severe COPD: the
8 London Chest Activity of Daily Living scale (LCADL). *Respir Med*. 2000;94(6):589-
9 596.
- 10 34. Banzett RB, O'Donnell CR, Guilfoyle TE, et al. Multidimensional Dyspnea Profile: an
11 instrument for clinical and laboratory research. *Eur Respir J*. 2015. 45(6): 1681-91.
- 12 35. Beaumont M, Couturaud F, Jago F, et al. Validation of the French version of the London
13 Chest Activity of Daily Living scale and the Dyspnea-12 questionnaire. *Int J Chron
14 Obstruct Pulmon Dis*. 2018;13:1399-1405. doi:10.2147/COPD.S145048
- 15 36. Gilet H, Pignier C, Aguilaniu B, et al. Psychometric Validation of the Multidimensional
16 Dyspnea Profile (Mdp) Questionnaire. *Value Health*. 2015;18(7):A712.
- 17 37. Jones PW, Quirk FH, Baveystock CM. The St George's Respiratory Questionnaire.
18 *Respir Med*. 1991;85 Suppl B:25-31; discussion 33-37.
- 19 38. Jones PW, Harding G, Berry P, Wiklund I, Chen WH, Kline Leidy N. Development and
20 first validation of the COPD Assessment Test. *Eur Respir J*. 2009;34(3):648-654.
- 21 39. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta Psychiatr
22 Scand*. 1983;67(6):361-370.

- 1 40. Yardley L, Beyer N, Hauer K, Kempen G, Piot-Ziegler C, Todd C. Development and
2 initial validation of the Falls Efficacy Scale-International (FES-I). *Age Ageing*.
3 2005;34(6):614-619.
- 4 41. Hellström K, Vahlberg B, Urell C, Emtner M. Fear of falling, fall-related self-efficacy,
5 anxiety and depression in individuals with chronic obstructive pulmonary disease. *Clin*
6 *Rehabil*. 2009;23(12):1136-1144.
- 7 42. Oliveira CC, McGinley J, Lee AL, Irving LB, Denehy L. Fear of falling in people with
8 chronic obstructive pulmonary disease. *Respir Med*. 2015;109(4):483-489.
- 9 43. Morgan BL, Voorhis CRWV. Understanding Power and Rules of Thumb for
10 Determining Sample Sizes. *Tutor Quant Methods Psychol*. 2007;3(2):43-50.
- 11 44. Pereira ACA, Xavier RF, Lopes AC, et al. The mini-balance evaluation system test can
12 predict falls in clinically stable outpatients with COPD: a 12-Mo prospective cohort
13 study. *J Cardiopulm Rehabil Prev*. 2019;39(6):391-396.
- 14 45. Beauchamp MK, Brooks D, Goldstein RS. Deficits in postural control in individuals
15 with COPD - emerging evidence for an important secondary impairment. *Multidiscip*
16 *Respir Med*. 2010;5(6):417-421.
- 17 46. Ozalevli S, Ilgin D, Narin S, Akkoclu A. Association between disease-related factors
18 and balance and falls among the elderly with COPD: a cross-sectional study. *Aging Clin*
19 *Exp Res*. 2011;23(5-6):372-377.
- 20 47. Janssens L, Brumagne S, McConnell AK, et al. Proprioceptive Changes Impair Balance
21 Control in Individuals with Chronic Obstructive Pulmonary Disease. Hug F, ed. *PLoS*
22 *ONE*. 2013;8(3):e57949. doi:10.1371/journal.pone.0057949

- 1 48. Hodges PW, Gandevia SC. Activation of the human diaphragm during a repetitive
2 postural task. *J Physiol*. 2000;522 Pt 1:165-175.
- 3 49. Hodges PW, Heijnen I, Gandevia SC. Postural activity of the diaphragm is reduced in
4 humans when respiratory demand increases. *J Physiol*. 2001;537(Pt 3):999-1008.
- 5 50. Sherrington C, Fairhall NJ, Wallbank GK, et al. Exercise for preventing falls in older
6 people living in the community. Cochrane Bone, Joint and Muscle Trauma Group, ed.
7 *Cochrane Database Syst Rev*. 2019;2019(1). doi:10.1002/14651858.CD012424.pub2
- 8 51. Delbressine JM, Vaes AW, Goërtz YM, et al. Effects of Exercise-Based Interventions on
9 Fall Risk and Balance in Patients With Chronic Obstructive Pulmonary Disease: A
10 SYSTEMATIC REVIEW. *J Cardiopulm Rehabil Prev*. 2020;40(3):152-163.
- 11 52. Ferraro FV, Gavin JP, Wainwright TW, McConnell AK. Comparison of balance changes
12 after inspiratory muscle or Otago exercise training. *PloS One*. 2020;15(1):e0227379.
13 doi:10.1371/journal.pone.0227379
- 14 53. Tounsi B, Acheche A, Lelard T, Tabka Z, Trabelsi Y, Ahmaidi S. Effects of specific
15 inspiratory muscle training combined with whole-body endurance training program on
16 balance in COPD patients: Randomized controlled trial. *PloS One*.
17 2021;16(9):e0257595. doi:10.1371/journal.pone.0257595
- 18 54. Liwsrisakun C, Pothirat C, Chaiwong W, et al. Exercise Performance as a Predictor for
19 Balance Impairment in COPD Patients. *Med Kaunas Lith*. 2019;55(5):E171.

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1 **FIGURES LEGENDS**

2 **Figure 1. The ROC curve for the logistic regression model is presented on the figure.**

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4 **Figure 2. The estimated marginal means of a reduced postural control are presented for**

5 **each identified predictor. The grey zone represents the 95% confidence interval.**

6 Abbreviations: SRGQ-S indicates Saint-George Respiratory Questionnaire-Symptoms score;

7 BMI indicates body mass index; MIP indicates maximal inspiratory pressure; PaO₂ indicates

8 partial arterial pressure in oxygen ; mmHg indicates millimeters of mercury ; cmH₂O indicates

9 centimeters of water ; kg/m² indicates kilograms per meter squared.

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Figure 1

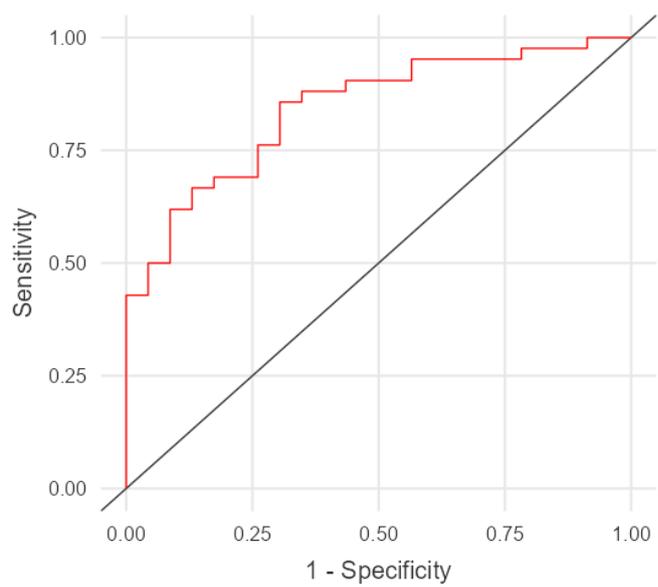
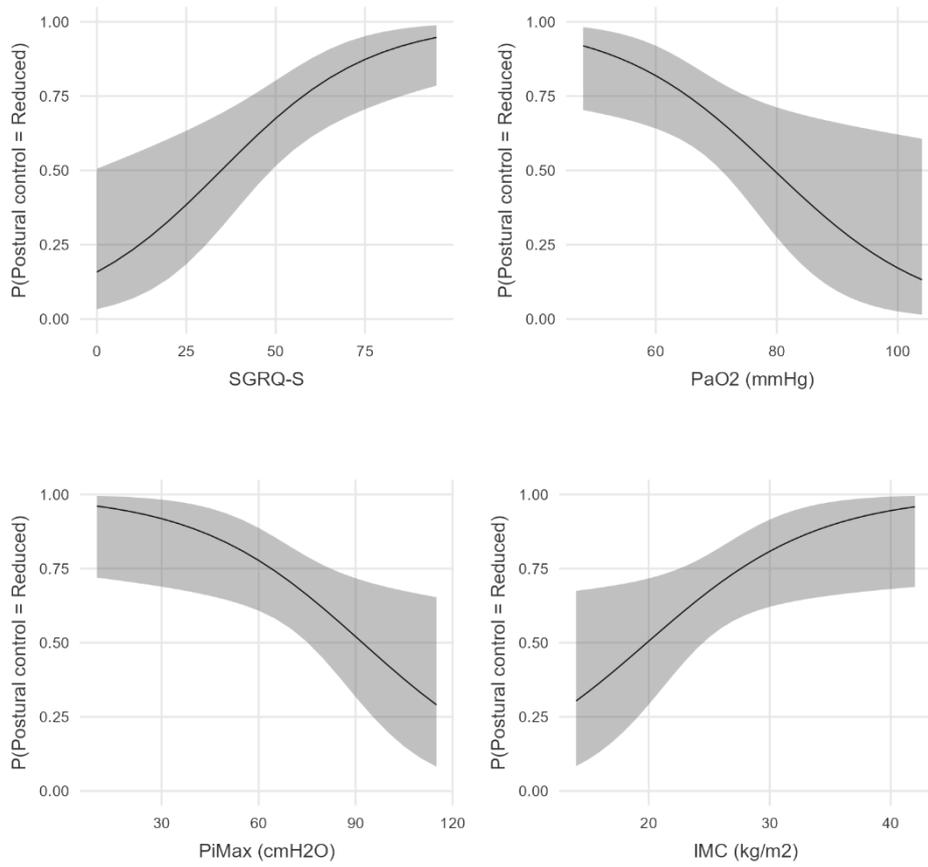


Figure 2



1 TABLES

2 Table 1. Characteristics of participants according to postural control status

Variables	All participants (n=73)	Non-reduced postural control group (n=26)	Reduced postural control group (n=43)	Between-group comparison (non-reduced versus reduced postural control)	
				P value	Effect size
Age, yr	66 (59, 70)	67 (62, 71)	65 (27, 69.5)	.225 ^T	.30 ^D
BMI, kg/m ²	26.6 ± 5.9	24.8 ± 6.5	27.5 ± 5.5	.072 ^T	-0.45 ^D
BBT	19 (16, 20)	21.3 ± 1.7	15.9 ± 3.2	< .001 ^M	.88 ^R
FEV1, %pred	40 (27, 55)	37 (27, 60.5)	42 (28, 50.5)	.877 ^M	.02 ^D
PaO ₂ , mmHg	67.5 ± 10.1	71.2 ± 11.2	65.3 ± 8.6	.019 ^T	.62 ^D
PaCO ₂ , mmHg	42 (39, 46.8)	42 (39.8, 45.3)	43 (39, 47.8)	.487 ^M	.10 ^R
MIP, cmH ₂ O	70.6 ± 24.2	75.3 ± 24.5	65.6 ± 22.2	.094 ^T	.42 ^D
QStrength, Nm	248 (174, 355)	193 (152, 377)	263 (211, 327)	.233 ^M	.18 ^R
QEnd, sec	39.3 (28.6, 47)	36.5 (28.5, 46)	41 (29, 48.5)	.383 ^M	.13 ^R
6MWT, m	395 ± 109	411 ± 116	380 ± 102	.253 ^T	.28 ^D
1STST, reps	20 (17, 25.5)	20.7 ± 5.7	21.2 ± 6.4	.725 ^T	.08 ^D
D12	16.6 ± 8.74	14.5 ± 8.4	17.8 ± 8.6	.125 ^T	-0.39 ^D
MMRC	2 (1, 3)	2 (1, 2.75)	2 (1, 3)	.400 ^M	.12 ^R
LCADL	25 (20, 35)	26 (20.3, 33.5)	24 (20, 35)	.965 ^M	.007 ^R
MDP A1	4 (3, 5.25)	4 (3, 5)	4 (3, 5.75)	.298 ^M	.15 ^R
MDP A2	1.5 (0, 6.75)	1 (0, 6.5)	2 (0, 6)	.660 ^M	.07 ^R
MDP QS	9 (4, 17.8)	7 (2.5, 11.8)	11 (5.5, 18)	.057 ^M	.31 ^R

SGRQ total	51.4 ± 15.5	45.2 ± 16.6	55.9 ± 12.8	.004 ^T	-0.75 ^D
SGRQ-S	53.2 ± 21.5	43.3 ± 22.8	60.7 ± 17.6	<.001 ^T	-0.88 ^D
SGRQ-A	70.4 ± 18.5	59.9 (49.5, 79.5)	73.0 (65.8, 86.1)	.020 ^T	-0.59 ^D
SGRQ-I	40.9 ± 17.7	30.1 (20.8, 49.8)	42.3 (33.9, 53.2)	.045 ^T	-0.51 ^D
CAT	19.0 ± 6.78	17.0 ± 7.4	20.3 ± 5.7	.040 ^T	-0.52 ^D
HAD-D	7.12 ± 4.08	6.35 ± 3.77	7.91 ± 4.09	.118 ^T	- 0.39 ^D
HAD-A	8.63 ± 4.09	7 (4, 10)	9 (6.5, 13)	.015 ^T	-0.63 ^D
FES-I	23 (19, 36)	21.5 (18, 32)	26 (20, 36)	.238 ^M	.17 ^R
Falls	0 fall n=53	0 fall n=17	0 fall n=32	.631 ^F	NA
	1 fall n=13	1 fall n=7	1 fall n=6		
	2 falls n=2	2 falls n=1	2 falls n=1		
	3 falls n=2	3 falls n=1	3 falls n=1		
	4 falls n=1	4 falls n=0	4 falls n=1		

BMI, body mass index; BBT, Brief BESTest; CAT, COPD Assessment test; D12, dyspnea-12; FES-I, Falls efficacy scale international; FEV1, forced expiratory volume in one second; HAD, Hospital anxiety and depression scale (A, anxiety score; D, depression score); LCADL, London chest activity of daily living questionnaire; MDP, multi-dimensional dyspnea profile; MIP, maximal inspiratory pressure; MMRC, modified medical research council scale; NA: not applicable; PaO₂, partial arterial pressure in oxygen; PaCO₂, partial arterial pressure in carbon dioxide; Qend, quadriceps endurance; Qstrength, quadriceps strength; SGRQ, Saint-George Respiratory Questionnaire (A, activity sub-score; I, Impact sub-score; S, symptoms sub-score; total, total score); 1STST, one minute sit-to-stand test; 6MWT, six minute walk-test; ^D Cohen effect size; ^F Fisher's exact test; ^M Mann-Whitney test; ^R Rank biserial correlation; ^T Independent Student t-test.

Data are presented as mean ± SD or median (IQR) or n. Bold indicates p values < 0.05

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1 **Table 2. Significant correlations between postural control score (BBT) and clinical**
 2 **factors in participants (n=73)**

Variables	BBT
FES-I	-0.30**
MIP	.34**
MMRC	-0.26*
SGRQ-I	-0.26*
SGRQ-S	-0.32**
SGRQ total	-0.31**
PaO ₂	.26*
6MWT	.27*

BBT, brief-BESTest; MIP, maximal inspiratory pressure; MMRC, modified medical research council scale; PaO₂, partial arterial pressure in oxygen; SGRQ, Saint-George Respiratory Questionnaire (I, Impact sub-score ; S: symptoms sub-score); 6MWT, six-minute walk test.

All correlations reported in the table 2 were calculated using Spearman's rho. * p < .05 ; ** p < .01.

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