Isokinetics and Exercise Science 28 (2020) 261–267
DOI 10.3233/IES-201147
IOS Press

Review Article

Isokinetic testing of muscle strength of older individuals with chronic obstructive pulmonary disease: An integrative review

Richard W. Bohannon
Department of Physical Therapy, College of Pharmacy and Health Sciences, Campbell University, Lillington, NC 27546, USA
Tel.: +1 910 814 4096; E-mail: bohannon@campbell.edu

Abstract.
BACKGROUND: Muscle weakness, though not the primary impairment accompanying chronic obstructive pulmonary disease (COPD), has been documented in patients with the disease.
OBJECTIVE: Describe isokinetic testing procedures and clinimetric findings associated with the isokinetic testing of older individuals with COPD.
METHODS: Relevant articles were identified by an electronic PubMed search using the search string "isokinet* AND (chronic obstructive pulmonary disease OR COPD)" and by a hand search.
RESULTS: Thirty-four potentially relevant articles were identified. Seven were excluded, leaving 27 for review. The articles provide considerable support for the validity of isokinetic strength testing of older patients with COPD. Little data are available that provides specific information on the reliability and responsiveness of the measures.
CONCLUSIONS: Research provides considerable evidence for the validity, limited evidence for the reliability, and no statistical evidence for the responsiveness of isokinetic testing of muscle strength among older adults with COPD.

Keywords: Muscle strength, measurement, clinimetrics

1. Introduction

Chronic obstructive pulmonary disease (COPD), which includes both chronic bronchitis and emphysema, is common among adults of all ages. In the United States, at least, the disease is most prevalent among adults 65 to 84 years of age [1]. As would be expected, patients with COPD have lung-related impairments (e.g., difficulty breathing) as well as activity limitations (e.g., walking long distances) resulting from their obstructive pathology. Though not as widely recognized, patients with COPD have also been shown to demonstrate impairments in skeletal muscle strength. While such impairments have been documented using hand-held and hand-grip dynamometers [2,3] and field tests such as the sit-to-stand test [4], isokinetic dynamometry is probably the most widely researched strength testing procedure applied to patients with the disease. This review addresses the use of isokinetic dynamometry with patients with COPD. Specifically, the review seeks to describe the isokinetic testing procedures that have been applied to older individuals with COPD and the clinimetric findings obtained using the procedures.

2. Methods

Potentially relevant articles were identified by a search of PubMed on February 18, 2020. The search string used was "isokinet* AND (chronic obstructive pulmonary disease OR COPD)." A hand-search was also conducted. Article titles and abstracts, and where warranted full text, were examined to determine whether articles identified by the searches addressed the isokinetic testing of muscle strength of individuals with COPD. Reviews and articles not written in English were excluded. Articles were also excluded if they failed to provide procedural specifics (e.g., dynamometer used), used a custom isokinetic dynamometer or ergometer, addressed only endurance or accumulated work, or presented no findings relevant to the clinimetric properties of isokinetic testing. Articles retained for this review were examined for information on the sample tested, procedural specifics (e.g., dynamometer used and muscle groups tested), and findings relevant to clinimetric properties (e.g., validity, reliability, and responsiveness).

3. Results and discussion

The PubMed search identified 32 potentially relevant articles. Two additional articles were found by a hand search. One article was eliminated as it was a protocol and presented no findings. Two other articles were excluded because they employed a cycle ergometer rather than a dynamometer. Three articles were rejected because they did not provide important procedural specifics. One article addressed only muscle endurance. Relevant information, therefore, from 27 articles is summarized alphabetically by author in Table 1 [5–31].

Information summarized in the Table shows that isokinetic dynamometers have been used extensively to measure strength of older adults with COPD (mean age of 63.0 to 74.1 years). Isokinetic testing of individuals with COPD has been conducted in at least 9 different countries, but testing has been reported most widely in Brazil and Canada. Utilization of some model of 5 different dynamometers has been described in the literature, but some type of Biodex has been employed most frequently. Most articles providing specifics of isokinetic testing have documented concentric moment at speeds of 30 to 270°/s with 60°/s being reported most frequently. Many articles, however, have not specified the mode of the moment tested or reported the measurement of eccentric or isometric moments. Several articles have reported moment normalized against body weight, or measures of work or power. Most research reports have focused on the isokinetic testing of limb muscles (particularly the knee flexors and extensors); no reports of trunk muscle strength were found.

The clinimetric properties of isokinetic testing of individuals with COPD have received considerable attention. Validity has been demonstrated most often by reports of less, though not necessarily significantly less, strength in patients with COPD than in healthy matched individuals [5–7,10,11,15,16,19,21–23,26,27]. Notably, these strength differences sometimes diminish or disappear when strength measures are normalized against body weight [6]. The validity of isokinetic strength measures has also been supported by significant correlations of isokinetic strength measures with other measures of muscle performance or changes in muscle performance (e.g., leg press and stairclimbing power) [8,17] and assorted measures of timed mobility (e.g., sit-to-stand, timed-up-and-go, gait time, and six-minute walk test) [8,14,17,30]. Interestingly, the isokinetic strength of some lower limb muscle groups has been correlated significantly, albeit weakly with balance measures [5]. Although isokinetic strength has been found to correlate significantly with VO_2 maximum and some other measures of exercise capacity [14,15,18] it has not been consistent in this regard [8]. Measures of disease severity, whether represented by pulmonary function tests [11,15] or GOLD classification [30] are not uniform in their relationship with measures of isokinetic strength.

This review revealed only three studies that addressed the reliability of isokinetic strength measures in COPD. Two reported relative reliability using test-retest intraclass correlation coefficients (0.82–0.97) for measurements obtained a week apart [20,25]. One of these two studies also reported relative reliability using minimal detectable changes (95%) [25]. The third study simply determined that strength did not differ significantly across sets [28].

This review includes numerous articles showing that isokinetic testing is sensitive to change in strength over time, whether the changes were the result of isokinetic training, another type of training, or some other kind of intervention [9,10,12,13,15,22–24]. This evidence notwithstanding, only one study reported distribution-based measures of responsiveness (minimal detectable changes) [25] and no study reported anchor-based measures of responsiveness (minimum clinically important difference).

The consistency with which muscle weakness has been demonstrated in COPD should alert clinicians to the importance of including the assessment of strength in the overall examination of individuals with the disease. The relationship of muscle strength with physical function and performance adds to the importance of

Table 1
Summary of studies describing the isokinetic measurement of strength in chronic obstructive pulmonary disease

Study	Participants	Procedures	Findings
Beuchamp et al. (2012) [5]	Canadians with COPD ($n = 37$, mean age = 71 y) & controls ($n = 20$, mean age = 67 y)	Biodex System 4 dynamometer measured bodyweight normalized peak isometric knee extension & flexion moment & ankle plantarflexion & dorsiflexion moment.	Validity: All normalized strengths for patients with COPD were SGNF < strengths for matched controls. SGNF correlation between BESTest & strength of knee flexors ($r = 0.43$) & extensors ($r = 0.42$) but not ankle plantarflexors or dorsiflexors. SGNF correlation between Berg Balance Test & strength of knee flexors ($r = 0.28$) & ankle dorsiflexors ($r = 0.31$) but not knee extensors or ankle plantarflexors.
Borghi-Silva et al. (2009) [6]	Brazilians with COPD ($n = 24$, mean age = 68 y) & controls ($n = 18$, mean age = 65 y)	Biodex System 3 dynamometer measured concentric knee extensor PT @60°/s, PT/body weight, total work & power.	Valiidity: Strength of patients with COPD on sham ventilation SGNF < controls. Peak moment/body weight was not SGNF different.
Van den Borst et al. (2013) [7]	Dutch with COPD ($n = 29$, mean age = 65 y) & controls ($n = 15$, mean age = 65 y)	Biodex dynamometer measured maximum dominant peak knee extensor moment @90°/s.	Validity: Strength of patients with COPD < controls but not SGNF.
Butcher et al. (2012) [8]	Canadians with COPD ($n = 13$, mean age = 74.1 y)	Humac NORM dynamometer measured dominant knee extension PT & PT/body weight @90°/s, 180°/s, 270°/s concentrically, 90°/s eccentrically, & isometrically.	Validity: All normalized strength measures correlated SGNF with all Timed up & go measures ($r = -0.69$ to -0.92), some stair climbing power test ($r = 0.57$ to 0.78), sit-to-stand test ($r = 0.54$ to 0.81) & steep ramp anaerobic test ($r = 0.57$ to 0.80) measures, but not cardiopulmonary exercise test results ($r = 0.06$ to 0.37).
Chen et al. (2017) [9]	Chinese with COPD assigned to intervention group ($n = 25$, mean age = 69.0 y) or control group ($n = 22$, mean age = 64.9 y)	CON-TREX dynamometer measured bilateral concentric knee extension PT & knee extension PT/bodyweight @60°/s & bilateral isometric knee extension PT & knee extension PT /bodyweight at 60°.	Responsiveness: All strength measures ↑ SGNF over 12 weeks in resistance training group. Some measures ↑ SGNF in control group.
Constantin et al. (2013) [10]	English with COPD ($n = 59$, mean age = 68 y) or healthy controls ($n = 21$, mean age = 66.1 y)	Cybex II Norm measured isometric knee extension PT, isokinetic knee extension PT & work over 5 repetitions @60°/s.	Validity: All strength measures of control group SIGN > COPD groups. Responsiveness: In COPD groups, isometric strength ↑ SGNF after 4 & 8 wk of resistance training.
Coratella et al. (2018) [11]	Italians men with COPD ($n = 35$, mean age = 65 y) & controls ($n = 25$, mean age = 65 y)	Cybex NORM measured concentric & eccentric knee extension PT @0.52 rad/s (slow) & 3.67 rad/s (fast) speeds & normalized against bodyweight.	Validity: Normalized concentric strengths of control group SGNF > COPD group. Normalized eccentric strengths of control group > COPD group but not SGNF. All strength measures of COPD group correlated SGNF ($r = 0.387$ to 0.495) with pulmonary function test results.
Corso et al. (2007) [12]	Brazilians with COPD undergoing neuromuscular electrical stimulation ($n = 17$, mean age = 65.9 y)	Con-Trex dynamometer measured concentric right knee extension PT @60°/s.	Responsiveness: Strength ↑ but not SGNF after electrical stimulation.
Creutzberg et al. (2003) [13]	Dutch with COPD assigned to intervention group ($n = 33$, mean age = 66) or placebo group ($n = 30$, mean age = 66 y)	Aristokin dynamometer measured isometric lower limb extension peak force against resistance of 2200N & isokinetic lower limb extension work @20 cm/s.	Responsiveness: Force & power ↑ SGNF in intervention group. Only force ↑ SGNF in placebo group.

Table 1, continued

Study	Participants	Procedures	Findings
Felisberto et al. (2018) [14]	Brazilians hospitalized with COPD ($n = 17$, mean ag = 70.9 y) or healthy older adults ($n = 11$, mean age = 71.0 y)	Biodex Multi Joint System III measured dominant elbow flexion & extension PT @90°/s.	Validity: Six-minute pegboard & ring test correlated SGNF with elbow flexion ($r = 0.52$) & extension ($r = 0.61$) strengths.
Franssen et al. (2004) [15]	Dutch with COPD ($n = 50$, mean age = 64 y) & healthy controls ($n = 36$, mean age = 61 y)	Biodex dynamometer measured dominant knee extension PT @90°/s. PT/fat free mass also determined.	Validity: Both baseline knee extension strength measures of control group SGNF > COPD group. Knee extension strength correlated SGNF with Vo_2max ($r = 0.54$), maximal work rate ($r = 0.40$), age ($r = -0.37$), & fat free mass (0.63) but not pulmonary function. Responsiveness: Whole body exercise resulted in a SGNF ↑ in knee extension strength for COPD group.
Janaudis-Ferreira et al. (2006) [16]	Swedes with COPD ($n = 42$, mean age = 64.7 y) & healthy controls ($n = 52$, mean age = 65.4 y)	KinCom measured mean concentric maximum knee extension & flexion force at 90°/s.	Validity: Strength of control group > COPD group. Difference SGNF for flexion in men & women & for extension in women.
Kongsgaard et al. (2004) [17]	Danes with COPD assigned to intervention group ($n = 6$, mean age = 71 y) or control group ($n = 7$, mean age = 73 y)	Kin-Com dynamometer measured self-reported strongest leg's maximal isometric knee extension force @60°/s & maximal concentric knee extension force @60°/s & 180°/s.	Validity: Changes in all strength measures intercorrelated SGNF ($r_s = 0.65$ to 0.88) & with changes in leg extension power ($r_s = 0.63$ to 0.82), gait time ($r_s = -0.56$ to -0.73), 5RM leg press ($r_s = 0.64$ to 0.87). Responsiveness: All strength measures ↑ SGNF with 12 wk resistance training.
Lopes et al. (2018) [18]	Brazilians with COPD ($n = 97$, mean age = 70.2 y)	Biodex System 4PRO dynamometer measured dominant side knee flexion and extension PT @75°/s.	Validity: Strength correlated SGNF with VO_2 max ($r = 0.41$).
Malaguti et al. (2011) [19]	Brazilians with COPD ($n = 39$, mean age = 63.5 y) & healthy controls ($n = 17$, mean age = 64.7 y)	CON-TREX dynamometer measured bilateral concentric knee extension PT @ 60°/s & isometric PT @60°/s.	Validity: Both strength measures of control group SGNF > COPD group. Strength of most COPD groups correlated SGNF with leg muscle mass ($r^2 = 0.29$ to 0.53).
Mathur et al. (2004) [20]	Canadians with COPD ($n = 20$, mean age = 63 y)	Cybex II dynamometer measured dominant concentric knee extension and elbow flexion PT @30°/s & 90°/s & isometric knee extension & elbow flexion PT @60° & 90°.	Reliability: Test-retest with 1 wk interval by 10 participants supported by ICCs of 0.82 to 0.96.
Medeiros et al. (20150 [21]	Brazilians with COPD ($n = 15$, mean age = 65.2 y) & controls ($n = 10$, mean age = 65.2 y)	CON-TREX dynamometer measured isometric knee extension PT @80°.	Validity: Strength of control group SGNF > COPD group.
Menon et al. (2012) [22]	English with COPD ($n = 17$, mean age = 66.7 y) & controls ($n = 10$, mean age = 66.7 y)	Cybex II Norm dynamometer used to measure isometric knee extension PT @70° & concentric knee extension PT @60°/s.	Validity: Both strength measures of control group > COPD group, but not SGNF. Responsiveness: After 8 wk of resistance training both strength measures ↑ SGNF in COPD group.
Menon et al. (2012) [23]	English with COPD ($n = 45$, mean age = 68.2 y) & controls ($n = 19$, mean age = 66.2 y)	Cybex II Norm measured dominant limb isometric knee extension PT @70°.	Validity: Strength of control group SGNF > COPD group. Responsiveness: Strength of COPD group ↑ SGNF after 8 wk resistance training.

Table 1, continued

Study	Participants	Procedures	Findings
Pleguezuelos et al. (2013) [24]	Spaniards with COPD assigned to a control group ($n = 25$, mean age = 71.3 y) or whole body vibration intervention group ($n = 26$, mean age = 68.4 y)	Biodex Advantage System dynamometer measured bilateral concentric knee extension & flexion PT @60°/s & 180°/s.	Responsivness: Six wk of vibration did not ↑ strength SGNF.
Ribeiro et al. (2015) [25]	Canadians with COPD ($n = 14$, mean age = 65 y)	Biodex System Pro 4 dynamometer measured concentric knee extension PT @90°/s & 180°/s.	Reliability: Test-retest with 5–7 day interval supported by ICC of 0.97, $MDC_{95\%}$ of 14 Nm, & $MDC_{95\%}$% of 12 for 90°/s & by ICC of 0.94, $MDC_{95\%}$ of 17 Nm, & $MDC_{95\%}$% of 19 for 180°/s.
Ribeiro et al. (2019) [26]	Canadians with COPD ($n = 14$, mean age = 65 y) & controls ($n = 14$, mean age = 67 y)	Biodex System Pro4 dynamometer measured concentric knee extension PT @90°/s.	Validity: Strength of control group SGNF > COPD group.
Roig et al. (2010) [27]	Canadians with COPD ($n = 21$, mean age = 71.2 y) or controls ($n = 21$, mean age = 71.2 y)	KinCom dynamometer measured the dominant knee flexion & extension concentric & eccentric PT @30°/s & isometric knee flexion & extension @90°.	Validity: All strength measures except for eccentric knee flexion were SGNF > for control group than for COPD group.
Vieira et al. (2010) [28]	Brazilians with COPD ($n = 20$, mean age = 66.1 y)	Biodex System 3 dynamometer measured dominant knee @60°/s.	Reliability: No SGNF difference in strength measurements across sets.
Villaça et al. (2008) [29]	Brazilians with COPD characterized as deleted ($n = 19$, mean age = 64.2 y) or non-deleted ($n = 29$, mean age = 29 y)	Con-TREX dynamometer measured right knee extension PT moment @60°/s.	Validity: Strength of depleted group SGNF > nondepleted group.
Van Wetering (2008) [30]	Dutch with COPD ($n = 127$, mean age = 67 y)	Biodex System3 measured dominant side isometric knee extension PT @60°.	Validity: Strength not SGNF different between GOLD stages. Strength related SGNF with 6 minute walk distance.
Wu et al. (2018) [31]	Chinese with COPD assigned to water-based exercise ($n = 14$, mean age = 65 y), land-based exercise ($n = 15$, mean age = 65 y), or a control ($n = 16$, mean age = 66 y)	CON-TREX dynamometer measured concentric elbow flexion & extension & knee flexion & extension PT & PT/body weight @60°/s.	Responsiveness: Strength did not ↑ SGNF in any group.

*COPD = chronic obstructive pulmonary disease, SGNF = significant/significantly, PT = peak moment.

examining muscle strength. Whether muscle weakness in COPD stems for the systemic nature of COPD [32] or physical inactivity [33] on the part of individuals with the disease, appropriate management of the disease requires that strength be addressed. Isokinetic dynamometry may be a superior method for such examination [34].

If isokinetic testing is to be recommended in COPD, further evidence for reliability and responsiveness are required. Although the reliability coefficients reported for isokinetic measurements in COPD are high [20,25], they were limited to test-retest reliability and derived from studies of less than 15 participants. Only one study provided objective estimates of absolute reliability or distribution-based responsiveness. These limitations, along with the absence of any anchor-based estimates of responsiveness, compromise the ability to establish meaningful goals. They also compromise the capacity to interpret changes in patient performance over time.

This review has several limitations. Most notably, only one bibliographic database (PubMed) was employed. While it is uncertain that the incorporation of additional databases would have markedly altered the results, a broader search may have provided more comprehensive evidence for the conclusions presented herein. A more systematic review may have also allowed for a meta-analysis of some variables and for a quality grading of included articles. Another limitation is the reliance on a single examiner (the author). Consequently, the quality check possible by including a second examiner was not possible.

4. Conclusion

There is considerable research support for measuring the isokinetic strength of older individuals with COPD-mostly in regard to validity. Further information on reliability and responsiveness is needed. In the meantime, it makes sense to include objective strength testing in the assessment of patients with COPD.

Conflict of interest

The author declares no conflict of interest.

References

[1] Akinbami LJ, Liu X. Chronic obstructive pulmonary disease among adults aged 18 and over in the United States, 1998–2009. NCHS Data Brief no 632011. Accessed March 11, 2020.

[2] O'shea SD, Taylor NF, Paratz JD. Measuring muscle strength for people with chronic obstructive pulmonary disease: retest reliability of hand-held dynamometry. Arch Phys Med Rehabil. 2007; 88(1): 32-36.

[3] Carson EL, Pourshahidi LK, Madigan SM, Baldrick FR, Kelly MG, Laird E, et al. Vitamin D status is associated with muscle strength and quality of life in patients with COPD: a seasonal prospective observational study. Int J Chron Obstruct Pulmon Dis. 2018; 28(13): 2613-2622.

[4] Fermont JM, Bolton CE, Fisk M, Mohan D, Macnee W, Cockcroft JR, et al. Risk assessment for hospital admission in patients with COPD; a multi-centre UK perspective observational study. PLoS One. 2020; 15(2); e0228940.

[5] Beauchamp MK, Sibley KM, Lakhani B, Romano J, Mathur S, Goldstein RS, et al. Impairments in systems underlying control of balance in COPD. Chest. 2012; 141(6): 1496-1503.

[6] Borghi-Silva A, Di Thomazzo L, Pantone CBF, Mendes RG, de Fatima Salvini T, Costa D. Respirology. 2009; 14: 537-544.

[7] van den Borst B, Slot IGM, Hellwig CACV, Vosse BAH, Kelders MCHM, Barreiro E, et al. Loss of quadriceps muscle oxidative phenotype and decreased endurance in patients with mild-to-moderate COPD. J Appl Physiol. 2013; 114: 1319-1328.

[8] Butcher SJ, Pikaluk BJ, Chura RL, Walkner MJ, Farthing JP, Maciniuk DD. Associations between isokinetic muscle strength, high level functional performance, and physiological parameters in patients with chronic obstructive pulmonary disease. Int J Chron Obstruct Pulmon Dis. 2012; 7: 537-542.

[9] Chen Y, Niu M, Zhang X, Qian H, Xie A, Wang Z. Effects of home-based lower limb resistance training on muscle strength and functional status in stable chronic obstructive pulmonary disease patients. J Clin Nurs. 2018; 27; e1022-e1037.

[10] Constantin D, Menon MK, Houchen Wolloff L, Morgan MD, Singh SJ, Greenhaff P et al. Skeletal muscle molecular responses to resistance training and dietary supplementation in COPD. Thorax. 2013; 68: 625-633.

[11] Coratella G, Rinaldo N, Schena F. Quadriceps concentric-eccentric force and muscle architecture in COPD patients vs healthy men. Hum Mov Sci. 2018; 59: 88-95.

[12] Corso SD, Nápolis L, Malaguti C, Gimenes AC, Albuquerque A, Nogueira CB, et al. Skeletal muscle structure and function in response to electrical stimulation in moderately impaired COPD patients. Respiratory Med. 2007; 101: 1236-1243.

[13] Creutzberg EC, Wouters EFM, Mostert R, Pluyers RJ, Schols AMWJ. A role of anabolic steroids in the rehabilitation of patients with COPD? Chest. 2003; 124: 1733-1742.

[14] Felisberto RM, Barros CF, Nucci KCA, Albuquerque ALP, Pauline E, Brito CMM, et al. COPD Is the 6-minute pegboard and ring test valid to evaluate upper limb function in hospitalized patients with acute exacerbation of COPD? COPD. 2018; 13: 1663-1673.

[15] Franssen FME, Broekhuizen R, Janssen PP, Wouters EFM, Schols WJ. Effects of whole-body exercise training on body composition and functional capacity in normal-weight patients with COPD. Chest. 2004; 125: 2021-2028.

[16] Janaudis-Ferreira T, Wadell K, Sundelin G, Lindström B. Thigh muscle strength and endurance in patients with COPD compared with healthy controls. Respiratory Med. 2006; 100: 1451-1457.

[17] Kongsgaard M, Backer V, Jørgensen K, Kjaer M, Beyer N. Heavy resistance training increases muscle size, strength and physical function in elderly male COPD-patients-a pilot study. Respiratory Med. 2004; 98: 1000-1007.

[18] Lopes AJ, Vigário PS, Hora AL, Deus CAL, Soares MS, Guimarães FS, Ferreira AS. Ventilation distribution, pulmonary diffusion and peripheral muscle endurance as determinants of exercise intolerance in elderly patients with chronic obstructive pulmonary disease. Physiol Res. 2018; 67: 863-874.

[19] Malaguti C, Napolis LM, Villaca D, Neder JA, Nery LE, Corso SD. Relationship between peripheral muscle structure and function in patients with chronic obstructive pulmonary disease with different nutritional status. J Strength Cond Res. 2011; 25: 1795-1803.

[20] Mathur S, Makrides L, Hernandez P. Test-retest reliability of isometric and isokinetic moment in patients with chronic obstructive pulmonary disease. Physiother Can. 2004; 56: 94-101.

[21] Medeiros WM, Fernandes MCT, Azevedo DP, de Freitas FFM, Amorim BC, Chiavegato LD, et al. Oxygen delivery-utilization mismatch in contracting locomotor muscle in COPD: peripheral factors. Am J Physiol Regul Integr Comp Physiol. 2015; 308: R105-R111.

[22] Menon MK, Houchen L, Singh SJ, Morgan MD, Bradding P, Steiner MC. Inflammatory and satellite cells in the quadriceps of patients with COPD and response to resistance training. Chest. 2012; 142: 1134-1142.

[23] Menon MK, Houchen L, Harrison S, Singh SJ, Morgan MD. Ultrasound assessment of lower limb muscle mass in response to resistance training in COPD. Respiratory Res. 2012; 13: 19.

[24] Pleguezuelos E, Pérez ME, Guirao L, Samitier B, Costea M, Ortega P, et al. Respirology. 2013; 18: 1028-1034.

[25] Ribeiro F, Lépine P, Garceau-Bolduc, Coats V, Allard F, Saey D. Test-retest reliability of lower limb isokinetic endurance in COPD: a comparison of angular velocities. COPD. 2015; 10: 1163-1172.
[26] Ribeiro F, Oueslati F, Saey D, Lépine P-A, Chambah S, Coats V, et al. Cardiorespiratory and muscle oxygenation responses to isokinetic exercise in chronic obstructive pulmonary disease. Med Sci Sports Exerc. 2019; 51: 841-849.
[27] Roig M, Eng JE, MacIntyre DL, Road JD, Reid WD. Associations of the stair climb power test with muscle strength and functional performance in people with chronic obstructive pulmonary disease: A cross-sectional study. Phys Ther. 2010; 90: 1774-1782.
[28] Vieira L, Bottaro Celes R, de Assiss Viegas CA, Silva CAM. Isokinetic muscle evaluation of quadriceps in patients with chronic obstructive pulmonary disease. Revista Portuguesa de Pneumologia. 2101; 16: 717-736.
[29] Villaça DS, Lerario MC, dal Corso S, Nápolis L, de Albuquerque PAL, Lazaretti-castro M, et al. Clinical value of anthropometric estimates of leg lean volume in nutritionally depleted and non-depleted patients with chronic obstructive pulmonary disease. Br J Nutr. 2008; 100: 380-386.
[30] van Wetering CR, van Nooten FE, Mol SJM, Hoogendoorn M, Rutten-van-Mölken MPMH. Systemic impairment in relation to disease burden in patients with moderate COPD eligible for a lifestyle program. Findings from the INTERCOM trial. Int J COPD. 2008; 3: 443-451.
[31] Wu W, Liu X, Liu J, Li P. Wang Z. Effectiveness of water-based Liuzijue exercise on respiratory muscle strength and peripheral skeletal muscle function in patients with COPD. COPD. 2018; 13: 1713-1726.
[32] Agusti A, Soriano JB. COPD as a systemic disease. COPD. 2008; 5: 133-138.
[33] Watz H, Waschki B, Meyer T, Magnussen H. Physical activity in patients with COPD. Eur Resp J. 2009; 33: 262-272.
[34] Andersen H, Jakobsen J. A comparative study of isokinetic dynamometry and manual muscle tsting of ankle dorsal and plantar flexors and knee extensors amd flexors. Eur Neurol. 1997; 37: 239-242.