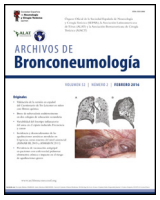
Archivos de Bronconeumología xxx (xxxx) xxx–xxx

Sociedad Española de Neumología y Cirugía Torácica SEPAR

ARCHIVOS DE
Bronconeumología

www.archbronconeumol.org



Scientific Letter

Identification of a Cut-Off Value to Identify Sarcopenia Through Pectoralis Muscle Area in Fibrotic ILDs: An International Study

To the Director,

Sarcopenia, characterized by reduced muscle mass and quality, is common in chronic respiratory diseases like interstitial lung diseases (ILD), particularly idiopathic pulmonary fibrosis (IPF) [1]. It is linked to poorer clinical outcomes and may benefit of early nutritional or rehabilitative interventions [2–7]. The gold standard for diagnosing sarcopenia involves specialized assessments by a nutritionist, but these may be delayed due to resource limitations [1]. Recent studies suggest that high-resolution computed tomography (HRCT)-derived thoracic muscle measurements could be an effective tool for diagnosing sarcopenia [2]. Specifically, single-slice cross-sectional area of pectoral muscles (PMA) at the 4th thoracic vertebra is a well-established method for assessing muscle mass and quality. HRCT provides advantages in ILD patients, as it is routinely used for diagnostic and follow-up purposes, allowing for body composition analysis without additional radiation or cost. This approach has been demonstrated to correlate with frailty and survival, particularly in oncologic and liver disease populations [8,9]. Our study aims to identify a cut-off value of PM index (PMI) in Caucasian patients with fibrotic ILDs to diagnose sarcopenia using chest HRCT.

We evaluated data from two cohort of patients: (i) an Italian cohort of consecutive adults with IPF from 4 Italian referral centers (Fondazione IRCCS San Gerardo dei Tintori, Monza; San Giuseppe Hospital, MultiMedica IRCCS, Milan; G. Salvini Hospital, Garbagnate Milanese and ASST Santi Paolo e Carlo, Milan) enrolled in the nutrIPF study (clinicaltrial.gov NCT03770845), whose clinical characteristics have been described before [10]; (ii) a Canadian cohort of consecutive adult patients with fibrotic ILDs (namely IPF, Hypersensitivity pneumonitis (HP) and idiopathic Non-specific Interstitial Pneumonia (NSIP)) from a single referral center in London, Canada, whose clinical characteristics have also been previously published [11].

For the purpose of this analysis we only included patients of Caucasian ethnicity and none of the patients was receiving systemic steroids at the time of the evaluation of sarcopenia.

The presence of sarcopenia was evaluated for both cohorts using the criteria developed by Baumgartner et al. [12], while for the Italian cohort the definition recommended by European Working Group on Sarcopenia in Older People 2 (EWGSOP2) 2019 (1) was also applied. We used the following references to define reduced Skeletal Muscle Index (SMI), measured through bioelectrical impedance analysis: SMI < 8.87 kg/m^2 for males and <6.42 kg/m^2 for females [13].

In contrast, the EWGSOP2 2019 criteria, are based on both muscle mass, strength and physical performance, and allow for the identification of patients with probable sarcopenia, in addition to those with overt sarcopenia (confirmed or severe). Muscle strength was evaluated through hand grip strength for both dominant and non-dominant limbs: measurements were performed by hand-held dynamometer (KERN MAP 1.2 version), repeated three times for each side and the best value was recorded [14]. BIA was performed using a standard tetra-polar technique with patients studied in the supine position with electrodes connected to the hands and feet (seca mBCA 525) [15].

The measurement of the PMA at HRCT scan was performed by two radiologists with 9 (C.M.) and 7 (D.G.G.) years of experience that did not have access to patients' information. The most recent unenhanced CT scan acquired within 3 months from the evaluation of sarcopenia was used for analysis. All CT examinations were performed on multi-detector scanners ranging from 64 to 256 slices. The chest CT acquisition parameters are reported in Supplementary Table 1.

Axial images at the level of the fourth thoracic vertebra (T4) were used for analysis. The total PMA was calculated as the sum of the bilateral pectoralis major and minor muscle areas. Muscle attenuation (density) within the same ROIs was measured in Hounsfield units. PMI was calculated as the ratio between PMA and height squared (cm^2/m^2).

This study received Ethics Committee approval (#1867, ASST Monza, October 2018 and Protocol No. 104028 and 103186, Western University Research Ethics Board).

A descriptive analysis was performed on the two cohorts using Fisher's exact test or the Mann–Whitney test for comparisons. In the Italian sample, the agreement between PMA measurements done by the two radiologists was evaluated using the Intraclass Correlation Coefficient (ICC).

PMI cut-offs for the prediction of overt sarcopenia were estimated separately for the two cohorts and on the whole pooled sample, by maximizing the Youden index for the area under the receiver operating characteristic (ROC) curve (AUC). Sensitivity and specificity of the identified cut-off was then assessed overall, and stratified by sex. 95% Confidence Intervals (95% CI) were computed through bootstrap method.

In the Italian cohort, we also conducted exploratory univariate multinomial logistic regression analyses using the three categories of sarcopenia as the outcome (no sarcopenia, probable sarcopenia, overt sarcopenia) and PMI as the predictor, in different forms.

In this study, we included two cohorts of Caucasian patients: the first cohort consisted of 59 Italian patients with IPF (median [IQR] age 72 [67–79] years, 20% female), and the second cohort included 28 Canadian patients with fibrotic interstitial lung disease (ILD), comprising 22 with IPF, 5 with NSIP, and 2 with HP. The median [IQR] age in the Canadian cohort was 71 [63–79] years, with 36%

https://doi.org/10.1016/j.arbres.2026.03.011

Please cite this article as: P. Faverio, D. Gandola, M. Mura et al., Identification of a Cut-Off Value to Identify Sarcopenia Through Pectoralis Muscle Area in Fibrotic ILDs: An International Study, Archivos de Bronconeumología, https://doi.org/10.1016/j.arbres.2026.03.011

Table 1
Description and comparison of the two study cohorts (Italian and Canadian).

Variable	Italian sample $N=59$	Canadian sample $N=28$	Total $N=87$	p-Value
Female gender	12 (20.34%)	10 (35.71%)	22 (25.29%)	0.1232
Median (IQR) age (years)	72 (67–79)	71 (63–79)	72 (66–79)	0.426
Overt sarcopenia	6 (10.17%)	12 (42.86%)	18 (20.69%)	0.0004
Median (IQR) weight (kg)	76.0 (69.0–82.0)	81.0 (65.5–101.1)	77.0 (67.0–83.5)	0.1938
Median (IQR) height (m)	1.68 (1.59–1.71)	1.69 (1.64–1.76)	1.68 (1.60–1.74)	0.2298
Median (IQR) BMI (kg/m^2)	26.78 (24.94–29.67)	28.75 (23.35–34.44)	26.99 (24.57–30.64)	0.3401
Obesity	16 (27.12%)	12 (42.86%)		0.142
Median ($Q1$–$Q3$) PMA (cm^2)	36.14 (31.14–42.01)	31.67 (26.06–39.83)	35.43 (28.87–41.70)	0.0414
Median ($Q1$–$Q3$) PMI (cm^2/m^2)	13.37 (11.18–15.93)	11.45 (9.60–13.63)	12.93 (10.78–14.85)	0.0073

Footnotes: BMI = body mass index; PMA = pectoralis muscle area; PMI = pectoralis muscle index.

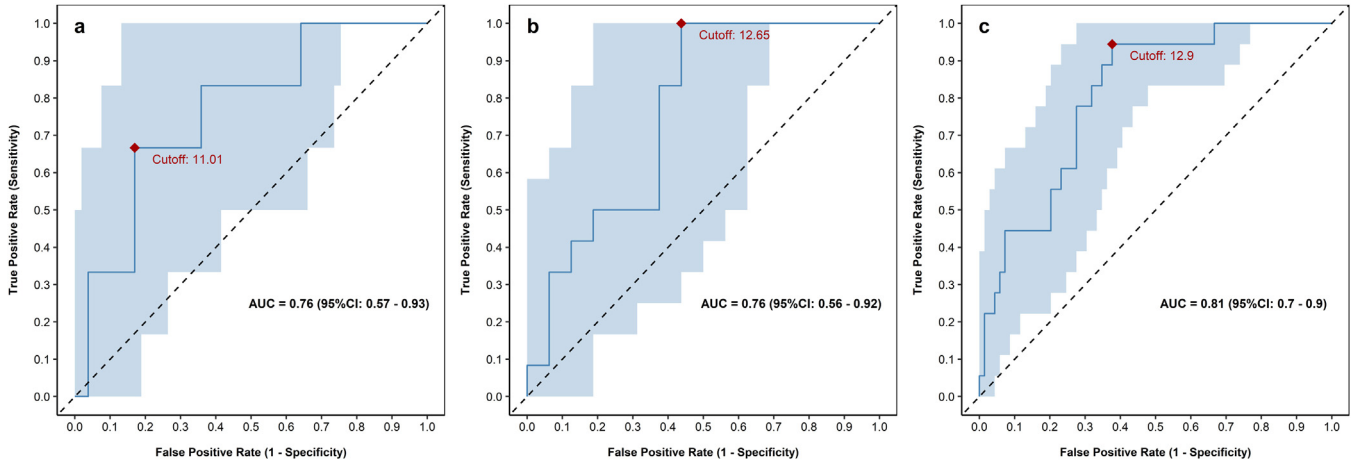


Fig. 1. Receiver operating characteristic (ROC) curve for PMI, reporting the Area Under the Curve (AUC) and the optimal cut-off point based on the Youden Index for the (a) Italian cohort, (b) Canadian cohort, (c) Italian + Canadian cohort.

female. The clinical characteristics of the study cohorts are summarized in Table 1, while characteristics stratified by sarcopenic status are reported in Supplementary Table 2.

In the Canadian cohort, 12 patients (42.9%) met the criteria for overt sarcopenia according to the definition by Baumgartner et al. In the Italian cohort, 6 patients (10.2%) were classified as having overt sarcopenia according to the criteria by Baumgartner et al., while using the 2019 EWGSOP2 criteria, which allow for staging of sarcopenia, 8 patients were identified with probable sarcopenia, and 6 had overt sarcopenia (3 patients each were classified as having confirmed and severe sarcopenia).

The ICC was 0.99 (95% CI: 0.99–1.00), demonstrating excellent concordance between observers in regards to PMA measurements.

In the Italian cohort the optimal cut-off PMI value (95%CI) to identify patients with overt sarcopenia was 11.01 (10.01–14.81) cm^2/m^2, with an AUC of 0.76 (95%CI: 0.57–0.93), p-value 0.04, Fig. 1a. The sensitivity and specificity (95%CI) of the cut-off were 0.83 (0.50–1.00) and 0.79 (0.34–0.98), respectively. In the Canadian cohort, the optimal cut-off PMI value (95%CI) to identify patients with overt sarcopenia was 12.65 (8.81–13.18) cm^2/m^2, with an AUC of 0.76 (95%CI: 0.56–0.92), p-value 0.02, Fig. 1b. The sensitivity and specificity (95%CI) of the cut-off were 1.00 (0.58–1.00) and 0.63 (0.38–0.94), respectively. By merging the two datasets into a single cohort of 87 patients, the optimal cut-off PMI value (95%CI) to identify patients with overt sarcopenia was 12.90 (10.00–12.90) cm^2/m^2, with an AUC of 0.81 (95%CI: 0.70–0.90), p-value < 0.001, Fig. 1c. The sensitivity and specificity (95%CI) of the cut-off were 0.94 (0.67–1.00) and 0.67 (0.54–0.93), respectively. When stratifying the sample by sex and applying the 12.90 cut-off, sensitivity and specificity were respectively 1.00 (1.00–1.00) and 0.40 (0.13–0.67) among females, and 0.91 (0.73–1.00) and 0.68 (0.56–0.80) among males.

In univariate multinomial logistic regression analyses PMI was considered as: (i) a continuous variable, (ii) a categorical variable using a cut-off of 12.9 cm^2/m^2, and (iii) a categorical variable with two thresholds set at 11 and 13 cm^2/m^2 (Table 2).

All three models confirmed an association between PMI and overt sarcopenia, with borderline statistical significance, more pronounced when using the categorical variables. No significant association was observed with probable sarcopenia.

Our study is the first to identify, in an international cohort of Caucasian patients with fibrotic ILDs, a PMI cut-off that predicts the presence of sarcopenia with good sensitivity and acceptable specificity. This finding has both strengths and limitations.

On one hand, this approach offers practical advantages: pulmonologists and radiologists can easily implement PMI assessment using chest HRCT routinely performed for IPF diagnosis and follow-up. Moreover, PMI measurement can be automated through artificial intelligence-based protocols [16]. The identified cut-offs showed high sensitivity with few false negatives but lower specificity with more false positives. As a screening rather than diagnostic tool, PMI may support early identification of ILD patients with sarcopenia and help select those requiring further evaluation according to 2019 EWGSOP2 criteria, also in light of multiple studies highlighting the importance of early identification of ILD patients with sarcopenia [17].

On the other hand, PMI alone may not detect probable sarcopenia and may be insufficient for early diagnosis. CT-based PMI assessment should therefore be complemented by physical performance measures such as the 6-minute walking test, 4-meter gait speed, or timed up and go.

Table 2
Results from multinomial univariate logistic regression models, evaluating variables associated with the probability of having probable or overt sarcopenia, with no sarcopenia as the reference category, in the Italian cohort.

Model	Variable	Probable vs no sarcopenia		Overt vs no sarcopenia	
		OR (95%CI)	*p*-Value	OR (95%CI)	*p*-Value
i	*PMI (1 unit decrease)*	1.111 (0.853–1.448)	0.435	1.523 (0.982–2.362)	0.060
ii	*PMI*				
	<12.9	1.087 (0.229–5.155)	0.916	**9.062 (0.972–84.450)**	**0.053**
	≥12.9	*Ref.*		*Ref.*	
iii	*PMI*				
	<11	1.929 (0.291–12.766)	0.496	**15.429 (1.481–160.766)**	**0.022**
	11–13	1.227 (0.196–7.700)	0.827	2.455 (0.141–42.823)	0.538
	≥13	*Ref.*		*Ref.*	

Footnotes: PMI = pectoralis muscle index.

The fact that the PMI cut-off identified to predict sarcopenia status differs slightly between the Italian (11.02 cm^2/m^2) and Canadian (12.65 cm^2/m^2) cohorts, despite both consisting of Caucasian patients with fibrotic ILDs, may be attributable to several factors. On one hand, there are currently no established parameters to standardize PMA values by weight and sex. As shown in the results, the Canadian cohort included a higher proportion of women and obese individuals compared to the Italian cohort. These differences may have contributed to the observed variation between the two populations.

Although our study is the first to propose PMI cut-off values for the prediction of sarcopenia, previous research has already demonstrated that PMA is a reliable surrogate for whole-body lean mass, and its reduction is associated with both markers of ILD severity, such as decreased forced vital capacity and diffusing capacity for carbon monoxide [18], and increased overall mortality in patients with IPF [4].

This study has several limitations. First, the small sample size prevented external validation and, although sensitivity and specificity were reported stratified by sex, the low sensitivity (0.40) observed in the female population may suggest that a lower cut-off would have been more appropriate for this group; however, the limited sample size and the low proportion of females among patients with IPF precluded further analysis.

To address this, we estimated bootstrap 95% confidence intervals for the cut-off and its performance measures to reflect result uncertainty and encourage validation in larger, multi-ethnic cohorts. Additionally, no validated formulas are available to adjust PMI for sex. Second, findings are limited to Caucasian patients with fibrotic ILD, reducing generalizability. Third, the 2019 EWGSOP2 criteria were applied only to the Italian cohort, while the Canadian cohort used a muscle mass–based definition, although patient selection substantially overlapped where both definitions were tested. This is due to the fact that the study was conducted prior to 2021; therefore, definitions of sarcopenia other than the 2019 EWGSOP2 criteria were also used. Fourth, our study included HRCT examinations acquired on different CT scanners with heterogeneous detector configurations and reconstruction algorithms. Although acquisition parameters were relatively standardized across centers, residual inter-scanner variability cannot be excluded and may partly contribute to the observed differences in PMI cut-off values between cohorts. Future multicenter studies with harmonized acquisition protocols are warranted to further improve the generalizability and reproducibility of the results.

In conclusion, a PMI cut-off of 12.90 cm^2/m^2 showed high sensitivity (94%) and moderate specificity (67%) for predicting sarcopenia in Caucasian patients with fibrotic ILDs. Integrated into routine chest CT evaluation, PMI may serve as a screening tool for overt sarcopenia, but it remains limited in detecting early or probable disease without complementary assessments of muscle strength and physical performance.

Authors' contributions

CM and PF are the guarantors of this research. PF, DG, MM, and CM were responsible for study concept and design. PF, DG, GF, MM, UZ, SH, AC, FB, MM, JC, AF, FL, DI and CM contributed to patient recruitment, follow-up and contributed to data acquisition. PF, SC and LGM performed data analysis. PF, SC and CM contributed to the drafting of this manuscript. All authors read and approved the final manuscript.

Statement of ethics

Our research complies with the guidelines for human studies and was conducted ethically in accordance with the World Medical Association Declaration of Helsinki.

Ethics approval

This study received Ethics Committee approval (#1867, ASST Monza, October 2018 and Protocol No. 104028 and 103186, Western University Research Ethics Board).

Consent for publication

All patients provided written informed consent at the time of enrolment.

Artificial intelligence involvement

Artificial intelligence was not used for the conduct and the writing of this study.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest of every author

The authors declare not to have any conflicts of interest that may be considered to influence directly or indirectly the content of the manuscript.

Availability of data and materials

Individual participant data referring to this article (i.e. text, tables and figures) will be made available upon reasonable request. Proposals should be directed to paola.faverio@unimib.it.

Acknowledgments

We acknowledge that this research was partially supported by the Grant: Italian MUR Dipartimenti di Eccellenza 2023-2027 (l. 232/2016, art. 1, commi 314-337).

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.arbres.2026.03.011.

References

[1] Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 2019;48(1):16–31.
[2] Sheehy R, McCormack S, Fermoyle C, Corte T. Sarcopenia in interstitial lung disease. Eur Respir Rev 2024;33:240126, http://dx.doi.org/10.1183/16000617.0126-2024.
[3] Faverio P, Fumagalli A, Conti S, Madotto F, Bini F, Harari S, et al. Sarcopenia in idiopathic pulmonary fibrosis: a prospective study exploring prevalence, associated factors and diagnostic approach. Respir Res 2022;23(1):228, http://dx.doi.org/10.1186/s12931-022-02159-7.
[4] Moon SW, Choi JS, Lee SH, Jung KS, Jung JY, Kang YA, et al. Thoracic skeletal muscle quantification: low muscle mass is related with worse prognosis in idiopathic pulmonary fibrosis patients. Respir Res 2019;20(1):35.
[5] Ibarra-Fernández AA, Robles-Hernández R, Orea-Tejeda A, González-Islas D, Jiménez-Valentín A, Sánchez-Santillán R, et al. Dynapenia and sarcopenia as risk factors for mortality in interstitial lung disease. Respirology 2025;30(5):424–34, http://dx.doi.org/10.1111/resp.14892.
[6] Cabrera-César E, Fernández-Jiménez R, Lopez-Garcia J, Sanmartín-Sánchez A, Benítez Cano-Gamonoso M, Asschert Agüero I, et al. Malnutrition sarcopenia, and malnutrition sarcopenia syndrome in idiopathic pulmonary fibrosis. Adv Respir Med 2025;93(3):11, http://dx.doi.org/10.3390/arm93030011.
[7] Fujikawa T, Kondo S, Saito T, Inoue T, Otake K, Misu S, et al. Impact of sarcopenia defined by carina-level skeletal muscle mass on the long-term prognosis of patients with idiopathic pulmonary fibrosis. Respir Med Res 2022;82:100965, http://dx.doi.org/10.1016/j.resmer.2022.100965.
[8] Panje CM, Höng L, Hayoz S, Baracos VE, Herrmann E, Garcia Schüler H, et al. Skeletal muscle mass correlates with increased toxicity during neoadjuvant radiochemotherapy in locally advanced esophageal cancer: a SAKK 75/08 substudy. Radiat Oncol 2019;14:166, http://dx.doi.org/10.1186/s13014-019-1372-3.
[9] Al-Azzawi Y, Albo B, Fasullo M, Coukos J, Watts GJ, Tai R, et al. Sarcopenia is associated with longer hospital stay and multiorgan dysfunction in alcoholic hepatitis. Eur J Gastroenterol Hepatol 2020;32(6):733–8, http://dx.doi.org/10.1097/MEG.0000000000001583.
[10] Faverio P, Fumagalli A, Conti S, Madotto F, Bini F, Harari S, et al. Nutritional assessment in idiopathic pulmonary fibrosis: a prospective multicentre study. ERJ Open Res 2022;8(1):00443-2021.
[11] Rinaldi S, Gilliland J, O'Connor C, Seabrook JA, Mura M, Madill J. Fat-free mass index controlled for age and sex and malnutrition are predictors of survival in interstitial lung disease. Respiration 2021;100(5):379–86, http://dx.doi.org/10.1159/000512732.
[12] Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, et al. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol 1998;147:755–63.
[13] Cruz-Jentoft AJ, Baeyens JB, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. Age Ageing 2010;39:412–23.
[14] Roberts HC, Denison HJ, Martin HJ, Patel HP, Syddall H, Cooper C, et al. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. Age Ageing 2011;40:423–9.
[15] Piccoli A, Brunani A, Savia G, Pillon L, Favaro E, Berselli ME, et al. Discriminating between body fat and fluid changes in the obese adult using bioimpedance vector analysis. Int J Obes Relat Metab Disord 1998;22:97–104.
[16] Genkin D, Jenkins AR, van Noord N, Makimoto K, Collins S, Stickland MK, et al. A fully automated pipeline for the extraction of pectoralis muscle area from chest computed tomography scans. ERJ Open Res 2024;10:00485-2023, http://dx.doi.org/10.1183/23120541.00485-2023.
[17] Zeng J, Liu J, He L, Zhu J, He J, Jiang J, et al. Sarcopenia in idiopathic pulmonary fibrosis: an updated systematic review and meta-analysis. Front Med (Lausanne) 2025;12:1681237, http://dx.doi.org/10.3389/fmed.2025.1681237.
[18] Molgat-Seon Y, Guler SA, Peters CM, Vasilescu DM, Puyat JH, Coxson HO, et al. Pectoralis muscle area and its association with indices of disease severity in interstitial lung disease. Respir Med 2021;186:106539, http://dx.doi.org/10.1016/j.rmed.2021.106539.

Paola Faverio[a,b,*], Davide Gandola[c], Marco Mura[d], Sara Conti[e], Umberto Zanini[a,b], Sergio Harari[f,g], Antonella Caminati[f], Francesco Bini[h], Michele Mondoni[i,j], Jacopo Cefalo[i], Giovanni Franco[a,b], Alessia Fumagalli[k], Lorenzo Giovanni Mantovani[l], Fabrizio Luppi[a,b], Davide Ippolito[a,c], Cesare Maino[c]

[a] *School of Medicine and Surgery, University of Milano-Bicocca, Italy*
[b] *SC Pneumologia, Fondazione IRCCS San Gerardo dei Tintori, Monza, Italy*
[c] *Department of Diagnostic Radiology, Fondazione IRCCS San Gerardo dei Tintori, Monza, Italy*
[d] *Department of Pathology and Laboratory Medicine, Western University, London, Canada*
[e] *Occupational Health Service, University of Milano Bicocca, Monza, Italy*
[f] *Division of Pulmonary and Respiratory Intermediate Care Unit, MultiMedica IRCCS, Milan, Italy*
[g] *Department of Clinical Sciences and Community Health, Università degli Studi di Milano, Milan, Italy*
[h] *Respiratory Unit, ASST Rhodense, Garbagnate Milanese, Milan, Italy*
[i] *Respiratory Unit, ASST Santi Paolo e Carlo, Milan, Italy*
[j] *Department of Health Sciences, Università degli Studi di Milano, Italy*
[k] *Respiratory Unit, ASST Nord Milano, Sesto San Giovanni, Milan, Italy*
[l] *Research Center on Public Health, University of Milano Bicocca, Italy*

Corresponding author.
E-mail address: paola.faverio@unimib.it (P. Faverio).