


30 s sit-to-stand power is positively associated with chest muscle thickness in COVID-19 survivors

Chronic Respiratory Disease
Volume 19: 1–10
© The Author(s) 2022
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/14799731221114263
journals.sagepub.com/home/crd


Rodrigo Núñez-Cortés^{1,2,3} , Carlos Cruz-Montecinos^{1,2,4}, Francisco Martínez-Arnau¹, Rodrigo Torres-Castro^{2,5} , Esteban Zamora-Risco³, Sofía Pérez-Alenda¹, Lars L. Andersen⁶, Joaquín Calatayud^{6,7} and Estanislao Arana⁸ 

Abstract

Introduction: After hospitalization, early detection of musculoskeletal sequelae might help healthcare professionals to improve and individualize treatment, accelerating recovery after COVID-19. The objective was to determine the association between the 30s sit-to-stand muscle power (30s-STs) and cross-sectional area of the chest muscles (pectoralis) in COVID-19 survivors.

Method: This cross-sectional study collected routine data from COVID-19 survivors one month after hospitalization: 1) a chest computed tomography (CT) scan and 2) a functional capacity test (30s-STs). The pectoralis muscle area (PMA) was measured from axial CT images. For each gender, patients were categorized into tertiles based on PMA. The 30s-STs was performed to determine the leg extension power. The allometric and relative STs power were calculated as absolute 30s-STs power normalized to height squared and body mass. The two-way ANOVA was used to compare the gender-stratified tertiles of 30s-STs power variants.

Results: Fifty-eight COVID-19 survivors were included (mean age 61.2 ± 12.9 years, 30/28 (51.7%/48.3%) men/women). The two-way ANOVA showed significant differences between the PMA tertiles in absolute STs power ($p = .002$) and allometric STs power ($p = .001$). There were no significant gender \times PMA tertile interactions (all variables $p > .05$). The high tertile of PMA showed a higher allometric STs power compared to the low and middle tertile, $p = .002$ and $p = .004$, respectively. Absolute STs power and allometric STs power had a moderate correlation with the PMA, $r = 0.519$ ($p < .001$) and $r = 0.458$ ($p < .001$) respectively.

Conclusion: The 30s-STs power is associated with pectoralis muscle thickness in both male and female COVID-19 survivors. Thus, this test may indicate global muscle-wasting and may be used as a screening tool for lower extremity functional capacity in the early stages of rehabilitation planning in COVID-19 survivors.

¹Department of Physiotherapy, Physiotherapy in Motion Multispeciality Research Group (PTinMOTION), University of Valencia, Valencia, Spain

²Department of Physical Therapy, Faculty of Medicine, University of Chile, Santiago, Chile

³Day Hospital Unit, Hospital Clínico Florida, Santiago, Chile

⁴Section of Research, Innovation and Development in Kinesiology, Kinesiology Unit, San José Hospital, Santiago, Chile

⁵International Physiotherapy Research Network (PhysioEvidence), Barcelona, Spain

⁶National Research Centre for the Working Environment, Copenhagen, Denmark

⁷Exercise Intervention for Health Research Group (EXINH-RG), Department of Physiotherapy, University of Valencia, Valencia, Spain

⁸Department of Radiology, Fundación Instituto Valenciano de Oncología, Valencia, Spain

Corresponding author:

Joaquín Calatayud, Exercise Intervention for Health Research Group (EXINH-RG), Department of Physiotherapy, University of Valencia, C/ Gascó Oliag 5. PC, Valencia 46010, Spain.

Email: joaquin.calatayud@uv.es



Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).

Keywords

Functional fitness, computed tomography, pectoralis muscle, SARS-CoV-2

Date received: 31 March 2022; accepted: 28 June 2022

Background

The SARS-CoV-2 (COVID-19) is an infectious disease with rapid transmission in the population.¹ Approximately 20% of the patients develop severe acute respiratory distress syndrome, and some cases require admission to the intensive care unit (ICU).² Current research shows marked loss of muscle strength after hospital discharge in COVID-19 patients without prior locomotor disabilities.³ Within the first 10 days of hospitalization, such patients can lose 17–30% of their muscle mass.⁴ In addition, functional performance – e.g. the ability to rise from a chair – of these patients can be seriously affected.^{5,6} The magnitude of the damage acquired in the ICU, in addition to pre-existing sarcopenia in many of the older and chronically ill patients acquiring COVID-19, can lead to muscle weakness, disability, and a lower quality of life.^{7,8}

In this context, the sit-to-stand (STS) test is a simple and accessible tool that can be used to measure the functional consequences of hospitalization after COVID-19.^{9,10} Both the 30 s STS (30s-STS) and the five times STS may be used as representative of lower limb functional capacity.¹¹ However, cardiorespiratory endurance is a more important determinant of performance in the 30s-STS.¹² In addition, to assess muscle power, the STS power obtained from the 30s-STS has been proposed as an easy, inexpensive and valid procedure to assess the bilateral lower limb power in older adults,¹³ being a good alternative in comparison with other validated and more sophisticated instruments.¹⁴ The 30s-STS muscle power test has been shown to be more strongly related with physical performance (i.e. maximal gait speed) than repetition-based STS performance in older population.¹³ Therefore, the low time, equipment and space requirements of the 30s-STS power make this test an excellent option for assessing the global state of the skeletal musculature, especially in pandemics, when precautionary measures and optimization of resources are most needed.

To assess the severity and prognosis of different respiratory chronic diseases such as chronic obstructive pulmonary disease (COPD),^{15,16} interstitial lung disease¹⁷ and also in patients with COVID-19,^{18,19} chest computed tomography (CT) has been widely used. For example, a higher pneumonia severity score (PSS), which assesses the severity of lung involvement, as well as a lower pectoralis muscle area (PMA) are significant predictors of prolonged hospital stay, intubation and mortality in adult patients with COVID-19.^{19,20} In fact, the pectoralis major and minor muscles are associated with breathing, assisting

inspiration.²¹ In addition, PMA has been used as an indicator of global muscle-wasting and the severity of various diseases. For example, in patients with interstitial lung disease, a condition similar to the lung deterioration caused by COVID-19,²² PMA is positively associated with lower limb physical performance (e.g. maximal voluntary contraction of the quadriceps),²³ and is an adequate surrogate for global muscle-wasting.¹⁷ In addition, PMA has shown a good association with other trunk muscles (e.g. erector spinae muscle or rectus abdominis muscle),²⁴ being also a good indicator of musculoskeletal mass, handgrip strength and physical activity level in COPD patients.²⁴ Cross-sectional area of the pectoralis muscle determined by low-dose chest CT scan is also significantly correlated with total body skeletal muscle mass, as measured by bioelectrical impedance analysis in healthy subjects²⁵ and has been associated with lean muscle mass, handgrip strength, sarcopenia, and outcomes in cancer and liver cirrhosis.^{26,27} Therefore, PMA appears to be an indicator of global muscle-wasting that can be used in COVID-19 survivors.

After hospitalization, early detection of musculoskeletal sequelae might help healthcare professionals, such as physicians and physiotherapists, to improve and individualize treatment, accelerating recovery after COVID-19. Although PMA appears to be an indicator of global muscle-wasting,²⁵ the economic cost of CT may be difficult to access for all patients, especially in rehabilitation settings. Therefore, there is a need to identify the association with simpler and cheaper clinical tools (i.e. 30s-STS power) to help assess global muscle-wasting.^{28,29} We hypothesize that the functional capacity of the lower limbs is associated with the global muscle wasting expressed by the PMA. The aim of the study was to determine the association between the 30s-STS power and the PMA in COVID-19 survivors. The secondary objective was to determine which is the best indicator of PMA, that is, the 30s-STS repetitions or the 30s-STS power.

Methods

Participants and design

A cross-sectional study that collected routine data from consecutive patients with COVID-19 was carried out at Hospital Clínico La Florida (Santiago, Chile). Patients entered the follow-up program to assess physical sequelae one month after discharge from the hospital between August and September 2020. Patients older than 18 years with a diagnosis of COVID-19 by reverse transcription-

polymerase chain reaction (PCR) were included in the study. Participants with limited mobility (i.e. inability to maintain a seated or bipedal position independently), inability to perform the test (i.e. not being able to sit and stand without arm support), joint pain in lower extremities, or hemodynamic instability (systolic blood pressure >180 mmHg or diastolic blood pressure >100 mmHg) were excluded. After discharge, all patients were admitted to a home rehabilitation program, which included 7–10 sessions of approximately 30 min over 3 weeks. Each session included breathing exercises, such as pursed-lip breathing and diaphragmatic breathing exercises, functional upper and lower limb exercises and walking. The exercise dose was based on patient tolerance. One month after discharge, the patients were evaluated with a chest computed tomography (CT) scan, which was a routine evaluation performed one month after hospitalization. Then, upon entry into the follow-up program, data were collected on the sociodemographic characteristics and the clinical history of the patients. Finally, a researcher blinded to the results of the CT image analysis performed the clinical evaluation. The study was approved by the Ethics Committee of the Southeast Metropolitan Health Service (Santiago, Chile) and was performed in accordance with the “Strengthening the Reporting of Observational Studies in Epidemiology” (STROBE) Guidelines.³⁰ Written informed consent was obtained from all participants during admission.

Computed tomography image acquisition and analysis

The CT scan images were obtained between August to September 2020 with a CT scanner (Bright Speed. 16, General Electric Healthcare, Buckinghamshire, United Kingdom). In the supine position, patients performed a deep inspiration.¹⁹ Standard CT images, due to their different windows, allow them to view and segment various tissues. CT images were acquired in a caudocranial direction using the following parameters: 0.5–0.7 s rotation time, 100 kV (kilovoltaje), 100–300 mA (milliamperes), 1.25 mm slice thickness and 1.25 slice reconstructions.

Image analysis was performed by a radiologist (EA, 27 years of experience in thoracic radiology) blinded to the clinical findings. The PSS was evaluated using a scoring method based on the percentage of involvement of each lung lobe, previously described by Chung et al.³¹ A higher PSS score indicates a more severe type of COVID-19. The PSS cutoff point of 7.5 has a high sensitivity for diagnosing severe-critical type COVID-19.³² On the other hand, the measure method was based on the Ufuk et al. Study¹⁹ to determine the cross sectional pectoralis muscle area (PMA, cm²). This protocol consists of identifying the axial slice just above the aortic arch. Then the radiologist performed a delimitation of the major and minor pectoral muscles

manually, using a predefined attenuation range of –50 and 90 Hounsfield unit (HU). When the breast tissue came into contact with the pectoral muscles, semi-automatic segmentation was performed. PMA was calculated by summing bilateral pectoralis major and minor muscle areas, with Horos software Version 3.3.3. Inter-observer agreement for PMA measurements in previous studies has been shown to be excellent (ICC = 0.919, 95%CI = 0.868–0.951).¹⁹ Then, the patients were divided into gender-stratified tertiles according to PMA for further analysis: First tertile (lowest), second tertile, and third tertile (highest). This categorization was also proposed in previous studies.^{15,19} The tertile cut-off values of PMA in males were <32 cm² for first, 32–37.2 cm² for second, and >37.2 cm² for third tertile, respectively. The tertile cut-off values of PMA in females were <23.4 cm² for first, 23.4–28.5 cm² for second, and >28.5 cm² for third tertile, respectively.

Clinical data

Exposure history and underlying comorbidities were collected and Charlson comorbidity index (CCI) was calculated.³³ Body Mass Index (BMI) was obtained from the ratio between weight and height squared (kg m²). Clinical frailty scale (CFS) was used to determine the daily functionality of the patient after hospitalization, CFS score ≥4 classifies patients as mildly vulnerable or having some degree of frailty.³⁴

Absolute, allometric and relative 30s-STs power test

The 30s-STs were performed to determine functional capacity. The 30s-STs was performed on the same day as the CT scan, after the CT scan, between 09:00 and 13:00 h. We decided to perform the 30s-STs only once considering that it has good test-retest reliability³⁴ and because the care time of each patient in our hospital is restricted. All tests were performed in the same room, with the same standard 46 cm high chair, without armrests, with only the assessor and the patient present to avoid distractions.³⁵ The patients were instructed to fold their arms across their chest and to complete as many sit-and-stand cycles as quickly as possible in 30 s. The patients were not allowed to use their arms during the chair rise. To stand, the legs had to be in full extension and to sit, the buttocks had to touch the chair. Verbal encouragement was given during the tests. The participants were allowed to practice 1–2 repetitions with a 60 s rest period before the STs measurement was recorded. The number of times that subjects were able to sit-and-stand during 30 s was used to then calculate the 30s-STs mean power (W) based on a method previously validated by Alcazar et al.,¹³ using the following equation:

The body mass is indicated in kg; 0.9 is a biomechanics-derived coefficient; g is the gravity (9.81 m·s⁻²); the vertical displacement traversed by the centre of mass was obtained

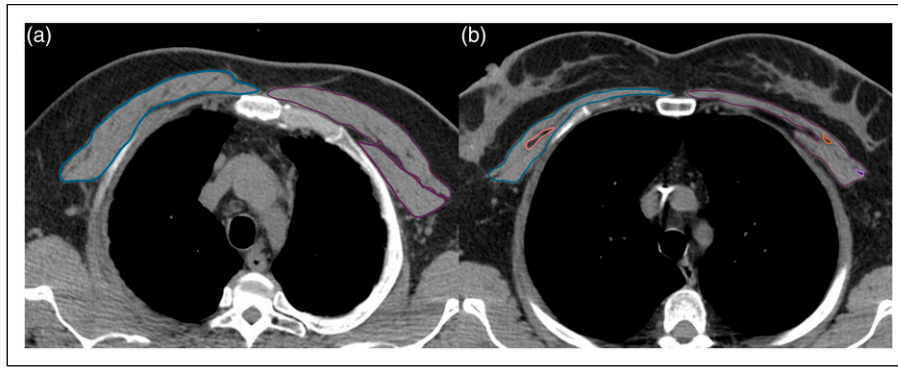


Figure 1. Chest computed tomography image of pectoralis muscle area (PMA) measurement.

$$30s - STS \text{ mean power} = \frac{\text{Body mass} \times 0.9 \times g \times [\text{Body height} \times 0.5 - \text{Chair height}]}{30s \times n \text{ of reps}^{-1} \times 0.5}$$

from the difference between the leg length and the chair height ($\text{body height} \times 0.5 - \text{chair height}$); the body height and height of the chair were indicated in m; 30s is the STS time; n of reps indicates the number of repetitions performed during the STS test; and 0,5 is a coefficient used to consider only the concentric phase, i.e. half of the test duration. For further analysis, the allometric STS power ($\text{W} \cdot \text{m}^{-2}$) was calculated by normalizing the absolute STS to the square of the height, because absolute muscle power is positively associated with height in both men and women.³⁶ The relative STS power ($\text{W} \cdot \text{kg}^{-1}$) was calculated by normalizing the STS power to body mass.^{28,29} The cut-off point proposed in the literature was $61.5 \text{ W} \cdot \text{m}^{-2}$ in women and $75.4 \text{ W} \cdot \text{m}^{-2}$ in men for allometric STS power and $2.1 \text{ W} \cdot \text{kg}^{-1}$ in women and $2.6 \text{ W} \cdot \text{kg}^{-1}$ in men for relative STS power.²⁹ Figure 1 shows an example about the measurement of PMA and related leg extension power.

Sample size

Sample size was calculated using G*Power software, version 3.1.9.2 (Universität Düsseldorf, Germany). Based on data from a prior study on the association of 30s-STs power and clinical variables of sarcopenia ($R^2 = 0.28$).¹³ Given a statistical power of 95%, a significance level of 0.05 and assuming a loss of 20% of participants, the minimum sample size required was 48 patients.

Statistical analyses

We conducted all statistical analyses in SPSS software (v. 22.0 for Windows, IL, USA). Shapiro-Wilk tests were used to verify a normal distribution. Values were expressed as mean \pm standard deviation (SD) or median and interquartile range according to the distribution. To assess the reliability of the cross-sectional area measurement method, the

intraclass correlation coefficients (ICC) was calculated between the left and right pectoral muscle. To compare the 30s-STs test and 30s-STs power between the PMA gender-stratified tertiles, the two-way analysis (gender \times PMA tertile) of variance (ANOVA) or Mann-Whitney U Test was used. Body mass index was included as covariate. A post-hoc test with Bonferroni correction for multiple comparisons was applied in case a significant difference between tertiles was observed. Moreover, a correlation analysis was applied using Pearson's or Spearman's correlation coefficients, depending on the distribution of the data, to assess the association between PMA and all 30s-STs test outcomes (repetitions, absolute, allometric or relative), and clinical variables obtained during the clinical evaluation: age, BMI, hospitalization days, and PSS. Statistical significance was set to $p < .05$. The parametric and nonparametric effect size between tertiles was calculated using Cohen's d or r conversion of the z-score (without sign) according to the distribution of data. The effect size of d and r can be interpreted as follows: d = 0.2 and r = 0.1, small; d = 0.5 and r = 0.3, medium; d = 0.8 and r = 0.5, large, respectively.³⁷

Results

A total of 72 patients were assessed for eligibility. Fourteen were excluded for the following conditions: severe mobility reduction ($n = 7$), low back pain ($n = 2$), hemodynamic instability ($n = 3$), declined to participate ($n = 2$) (Figure 2). Finally, 58 patients were included in the study (Table 1). The median age was 61.2 ± 12.9 years, and 30 (51.7%) patients were male. Sixty-four percent of patients had an allometric STS power below normative values, while 69% had a relative STS power below normative values. The median PSS was above the cutoff value of 7.5 points in both men and women, and 78% of patients were above the cutoff value. The CFS

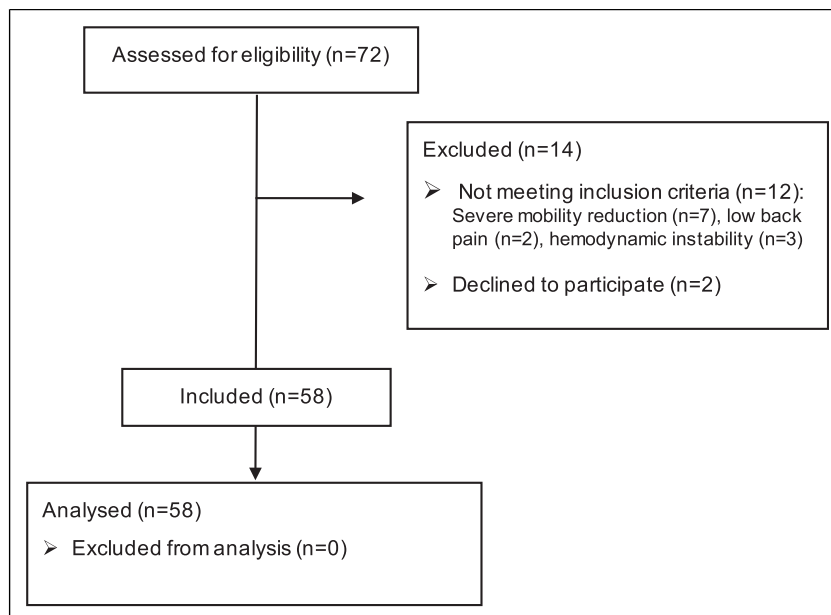


Figure 2. Patient flow diagram.

Table 1. Clinical characteristics of patients.

Characteristic	Total (n = 58)	Male (n = 30)	Female (n = 28)	p-Value	ES
Age (mean ± SD)	61.2 ± 12.9	61.9 ± 12.4	60.4 ± 13.5	0.638	0.12
BMI (mean ± SD)	30.2 ± 5.3	28.9 ± 5.8	31.6 ± 5.8	0.043*	0.46
ICU admission, n (%)	17 (29.3)	10 (33.3)	7 (25.0)	0.342	0.18
Hospitalization days (mean ± SD)	19.0 ± 14.5	16.1 ± 16.1	21.7 ± 12.5	0.140	0.39
PSS (points)	12.0 (5.0)	12.0 (4.3)	10.5 (8.5)	0.251	0.15
Charlson comorbidity index (points)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	0.687	0.05
Clinical frailty scale (points)	3.0 (2.0)	3.0 (2.0)	3.5 (1.0)	0.247	0.15
30s-STST test (repetitions)	10.5 ± 2.3	10.2 ± 2.0	10.7 ± 2.5	0.361	0.22
STS power (W)	171.8 ± 50.9	185.8 ± 45.0	156.8 ± 53.6	0.029*	0.59
Allometric STS power (W·m ⁻²)	64.6 ± 16.6	65.5 ± 14.5	63.6 ± 18.8	0.672	0.13
Relative STS power (W·kg ⁻¹)	2.2 ± 0.5	2.3 ± 0.5	2.0 ± 0.6	0.068	0.54
PMA (cm ²)	31.4 ± 8.8	35.7 ± 7.9	26.9 ± 7.2	<0.001**	1.16

30s: 30-s; BMI: body mass index; kg: kilograms; m: meters; PMA: pectoralis muscle area; PSS: pneumonia severity score; SD: standard deviation; STS: sit-to-stand; W: watts. ES: effect size (Cohen's d or r according to the distribution of data). Data are presented as mean ± SD or median (interquartile range) unless otherwise indicated.

*Statistically significant difference ($p < 0.05$), **Statistically significant difference ($p < .001$).

classified 43% of patients as having some degree of frailty. 17 cases (29%) required admission to the ICU during hospitalization, with an average of 14.3 ± 7.9 days of mechanical ventilation. Only one patient required supplemental oxygen during evaluation at one month after discharge. The ICC of the cross-sectional area measurement method, between the left and right pectoral, was 0.908 (95% CI = 0.845 to 0.946, $p < .001$).

The two-way ANOVA showed significant mean effect between the PMA tertiles groups in the absolute STS power ($F = 6.822, p = .002, \eta_p^2 = 0.208$) and allometric STS power ($F = 8.261, p = .001, \eta_p^2 = 0.241$). The BMI as a covariate

showed a non-significant interaction for PMA with 30s-STST power ($p = .925$) and allometric STS power ($p = .069$). There were non-significant differences when comparing the number of repetitions in the 30s-STST and relative STS power between the PMA tertiles, $p = .196$ and $p = .472$, respectively. Regarding gender, only a significant mean effect was observed between the PMA tertiles groups in the absolute STS power ($F = 6.822, p = .002, \eta_p^2 = 0.208$). In addition, there was no PMA tertile x gender interaction in all variables ($p > .05$), see Table 2. In post-hoc test (Table 3), the third tertile showed a higher absolute STS power in

Table 2. Results of two-way ANOVA.

Characteristic	Factor	F	p-Value	η_p^2
30s-STs test (repetitions)	PMA tertile	1.688	0.195	0.061
	Gender	0.898	0.348	0.017
	PMA tertile \times gender	0.951	0.393	0.035
Absolute STS power (W)	PMA tertile	6.822	0.002*	0.208
	Gender	5.641	0.021*	0.098
	PMA tertile \times gender	1.657	0.201	0.060
Allometric STS power (W·m ⁻²)	PMA tertile	8.261	0.001*	0.241
	Gender	0.151	0.699	0.003
	PMA tertile \times gender	1.642	0.203	0.059
Relative STS power (W·kg ⁻¹)	PMA tertile	0.846	0.435	0.032
	Gender	3.334	0.074	0.060
	PMA tertile \times gender	1.869	0.165	0.067

30s: 30-s; kg: kilograms; m: meters; PMA: pectoralis muscle area; STS: sit-to-stand; W: watts.

*Statistically significant difference ($p < .05$). eta partial square (η_p^2) indicates the effect size.

Table 3. Comparison between pectoralis muscle area tertiles.

Characteristic	PMA tertiles			First versus Second	First versus Third	Second versus Third
	First (n = 20)	Second (n = 19)	Third (n = 19)	p-value (ES)	p-value (ES)	p-value (ES)
30s-STs test (repetitions)	10.8 \pm 1.8	9.7 \pm 2.6	11.0 \pm 2.3	0.503 (0.49)	1.000 (0.10)	0.272 (0.53)
Absolute STS power (W)	152.8 \pm 39.7	161.3 \pm 43.5	202.3 \pm 56.4	1.000 (0.20)	0.005* (1.01)	0.029* (0.81)
Allometric STS power (W·m ⁻²)	58.9 \pm 11.7	59.3 \pm 14.4	75.7 \pm 18.0	1.000 (0.03)	0.002* (1.11)	0.004* (1.01)
Relative STS power (W·kg ⁻¹)	2.1 \pm 0.5	2.1 \pm 0.6	2.3 \pm 0.6	1.000 (0.00)	1.000 (0.36)	0.643 (0.33)

30s-STs: 30-s; kg: kilograms; m: meters; PMA: pectoralis muscle area; STS: sit-to-stand; W: watts. Data are presented as mean \pm SD unless otherwise indicated.

*Statistically significant difference ($p < .05$); ES, effect size (Cohen's d).

comparison to the first tertile (mean difference: -49.4, 95% CI: -86.6 to -12.3, $p = .005$) and second tertile (mean difference: -40.9, 95% CI: -78.5 to -3.3, $p = .029$). Also, the third tertile showed a higher allometric STS power in comparison to the first (mean difference: -17.1, 95% CI: -28.8 to -5.3, $p = .002$) and second tertile (mean difference: -16.7, 95% CI: -28.6 to -4.7, $p = .004$).

Correlations between PMA and 30s-STs test outcomes and clinical variables are displayed in [supplemental material \(S1\)](#). Age and BMI had a low correlation with PMA, $r = -0.280$ ($p = .33$) and $r = 0.303$ ($p = .021$) respectively, while the PMA did not correlate with the PSS and the days of hospitalization ($p < .05$). Relative STS power and 30s-STs repetitions were not correlated with PMA ($p > 0.05$). While absolute STS power and allometric STS power had a moderate correlation with the PMA, $r = 0.519$ ($p < .001$) and $r = 0.458$ ($p < .001$) respectively ([Figure 3](#)).

Discussion

The findings of this study showed that there is a significant association between the PMA and the absolute and

allometric STS power in COVID-19 patients after hospital discharge, with a large effect size, $\eta_p^2 = 0.208$ and $\eta_p^2 = 0.242$ respectively. Both relative STS power and the number of repetitions in the 30s-STs had non-significant correlation with PMA. Taking into account gender differences in absolute 30s-STs power, allometric 30s-STs power was the best indicator of differences in PMA. These results confirm our hypothesis that lower limb muscle power is associated with global muscle-wasting as expressed by PMA.

The number of repetitions and relative power in the 30s-STs were not associated with PMA. One possible explanation for these results is that the number of repetitions in the 30s-STs test does not take into account the normalization of values with respect to anthropometric characteristics (e.g., body height) and high chair. On the other hand, relative muscle power depends on BMI. In this context, the relative STS power may be non-specific, and it might be better to normalize to muscle mass. For example, Alcazar et al.²⁹ proposed the use of dual energy X-ray absorptiometry (DXA) or bioelectrical impedance analysis to estimate regional skeletal muscle mass in older adults. However, for clinical application, when DXA is not

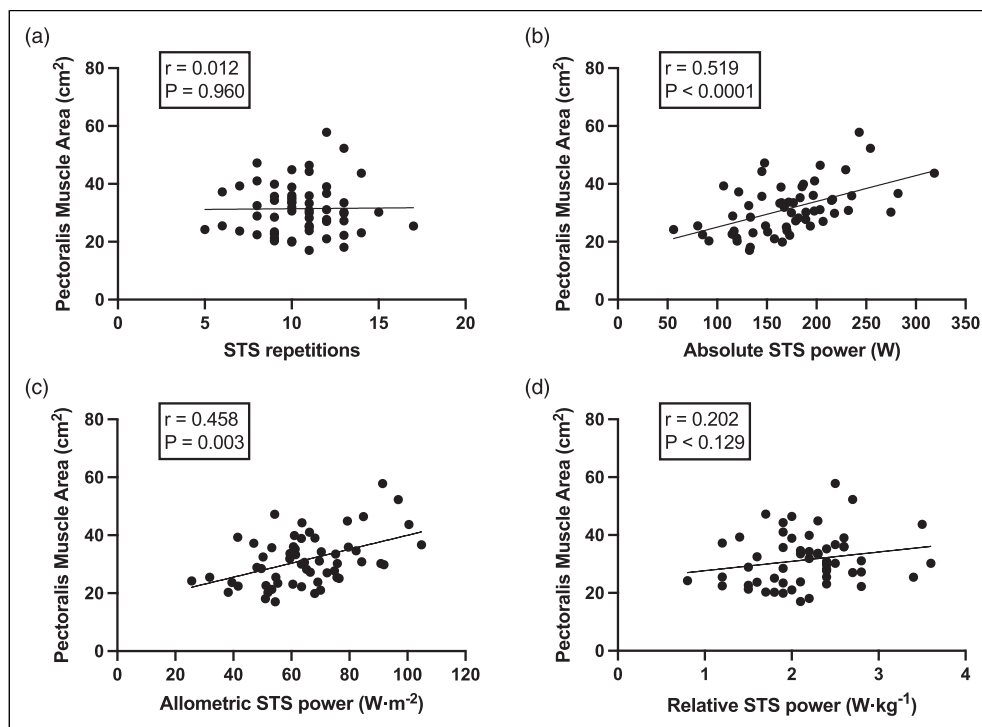


Figure 3. (a) Correlation between 30s-STs repetitions and pectoralis muscle area (PMA). (b) Correlation between absolute 30s-STs and PMA, (c) Correlation between allometric 30s-STs and PMA, and (d) Correlation between relative 30s-STs and PMA.

available, allometric STS power appears to be a good parameter to associate with pectoralis muscle thickness in COVID-19 survivors. Absolute muscle power is positively associated with height in both men and women.³⁶ The latter suggests that normalization by height should be considered as a first option for normalization of muscle 30s-STs in COVID-19 survivors.

The pectoral muscle area was also smaller in women, which agrees with that of healthy subjects, and people with chronic respiratory disease.^{16,25} On the other hand, patients in the lowest PMA tertile showed, on average, lower muscle power values than the cut-off point proposed in the literature (61.5 W·m⁻² in women and 75.4 W·m⁻² in men for allometric STS power and 2.1 W·kg⁻¹ in women and 2.6 W·kg⁻¹ in men for relative STS power).²⁹ This information could be useful for healthcare professionals (e.g., physicians and physiotherapists) and might help to identify the most vulnerable patients who require early intervention, considering that muscle power is strongly related to all-cause mortality, regardless of physical activity, muscle mass, and muscle strength.³⁸

Muscle strength and sarcopenia are independent risk factors for COVID-19 severity in adults over 50 years of age, while COVID-19 is directly associated with the onset of acute sarcopenia due to inactivity and bedrest.³⁹ This makes early detection of muscle strength loss necessary to ensure correct management of the disease and of its

consequences.³⁹ Within the difficulty in the detection of sarcopenia, STS has been shown to be useful as a technique for assessing lower limb strength,⁴⁰ mainly in the older population, with greater sensitivity in the early detection of cases than other common methods such as the handgrip strength.⁴¹ Among the alternatives to the STS test,²⁹ it is necessary to highlight the usefulness of 30s-STs power test as the method with the highest correlation with physical performance in older people and in particular the novelty obtained in the results of our study, with the allometric STS power as indicator of chest muscle thickness. However, the indicated global muscle-wasting by 30s-STs power is most likely related to hypokinesia and not to the direct influence of COVID-19 infection, so similar results should be expected in any disease requiring hospitalization (and thus limitation of physical activity), especially in people treated in the intensive care unit.⁴

After hospitalization, the early detection of musculo-skeletal sequelae may help develop more specialized interventions for early and adequate recovery in patients post COVID-19.⁴² Although muscle power is considered one of the main therapeutic objectives in older adults, in patients post COVID-19, the assessment of muscle power should be within a comprehensive evaluation that considers loss of independence in activities of daily living,⁴³ impaired respiratory function,⁴⁴ comorbidity burden,⁴⁵ and social risk factors.⁴⁶ In this context, multidisciplinary health care teams

must consider all these aspects when implementing the best strategies to improve the functionality and quality of life of COVID-19 survivors.⁴⁷ For example, considering lower extremity strengthening based on 30s-STs power findings.

Limitations

This study has some limitations. First, the level of evidence for these findings is limited to the nature of the cross-sectional design and causality cannot be established, nor the sense of direction of the association. Hence, it is difficult to establish a relationship without knowing where the patients started from (baseline reference in the diagnosis) and how much muscle mass was lost. Considering the average BMI of the sample, it is most likely that physical capacity was low even before hospitalization, which could also affect the general condition of the patients, as well as the more severe course of COVID-19. Second, we do not have muscle power values prior to hospitalization for COVID-19, it is reasonable to assume that an element of natural recovery occurred in at least some of the participants. Thus, future studies should assess whether a prospective association between these measurements exist. Third, the thresholds used as cut-off points for low muscle power were taken from a European cohort as they are not available for our country. Finally, the highest PMA tertile had a higher BMI. Although BMI as a covariate did not influence the ANOVA model, PMA measurements do not consider muscle quality, which could have a higher correlation with functional impairment.⁴⁸ This could also be an aspect to assess in future studies.

Conclusion

The 30s-STs power is associated with pectoralis muscle thickness in both male and female COVID-19 survivors. Thus, this test may indicate global muscle-wasting and may be used as a screening tool for lower extremity functional capacity in the early stages of rehabilitation planning in COVID-19 survivors.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Rodrigo Nunez-Cortes  <https://orcid.org/0000-0002-4068-9338>
 Rodrigo Torres-Castro  <https://orcid.org/0000-0001-7974-4333>
 Estanislao Arana  <https://orcid.org/0000-0002-1884-7854>

Supplemental Material

Supplemental material for this article is available online.

References

1. WHO. Coronavirus (COVID-19) Dashboard. <https://covid19.who.int> (accessed 22 June 2022).
2. Ozma MA, Maroufi P, Khodadadi E, et al. Clinical manifestation, diagnosis, prevention and control of SARS-CoV-2 (COVID-19) during the outbreak period. *Infez Med* 2020; 28: 153–165.
3. Paneroni M, Simonelli C, Saleri M, et al. Muscle strength and physical performance in patients without previous disabilities recovering from COVID-19 pneumonia. *Am J Phys Med Rehabil* 2021; 100: 105–109.
4. Puthuchery ZA, Rawal J, McPhail M, et al. Acute skeletal muscle wasting in critical illness. *JAMA* 2013; 310: 1591–1600.
5. Núñez-Cortés R, Rivera-Lillo G, Arias-Campoverde M, et al. Use of sit-to-stand test to assess the physical capacity and exertional desaturation in patients post COVID-19. *Chron Respir Dis* 2021; 18: 1479973121999205.
6. Candan SA, Elibol N, Abdullahi A, et al. Consideration of prevention and management of long-term consequences of post-acute respiratory distress syndrome in patients with COVID-19. *Physiother Theor Pract* 2020; 36: 663–668.
7. Herridge MS, Tansey CM, Matté A, et al. Functional disability 5 years after acute respiratory distress syndrome. *N Engl J Med* 2011; 364: 1293–1304.
8. Paris M and Mourtzakis M. Assessment of skeletal muscle mass in critically ill patients: considerations for the utility of computed tomography imaging and ultrasonography. *Curr Opin Clin Nutr Metab Care* 2016; 19: 125–130.
9. Belli S, Balbi B, Prince I, et al. Low physical functioning and impaired performance of activities of daily life in COVID-19 patients who survived hospitalisation. *Eur Respir J* 2021; 56: 2002096.
10. Holland AE, Malaguti C, Hoffman M, et al. Home-based or remote exercise testing in chronic respiratory disease, during the COVID-19 pandemic and beyond: A rapid review. *Chronic Respir Dis* 2020; 17: 147997312095241.
11. Jerez-Mayorga D, Delgado-Floody P, Intelangelo L, et al. Behavior of the muscle quality index and isometric strength in elderly women. *Physiol Behav* 2020; 227: 113145.
12. Yee XS, Ng YS, Allen JC, et al. Performance on sit-to-stand tests in relation to measures of functional fitness and sarcopenia diagnosis in community-dwelling older adults. *Eur Rev Aging Phys Act* 2021; 18: 1.
13. Alcazar J, Kamper RS, Aagaard P, et al. Relation between leg extension power and 30-s sit-to-stand muscle power in older adults: validation and translation to functional performance. *Sci Rep* 2020; 10: 16337.
14. Alcazar J, Losa-Reyna J, Rodriguez-Lopez C, et al. The sit-to-stand muscle power test: an easy, inexpensive and portable procedure to assess muscle power in older people. *Exp Gerontol* 2018; 112: 38–43.

15. Bak SH, Kwon SO, Han S-S, et al. Computed tomography-derived area and density of pectoralis muscle associated disease severity and longitudinal changes in chronic obstructive pulmonary disease: a case control study. *Respir Res* 2019; 20: 226.
16. McDonald M-LN, Diaz AA, Ross JC, et al. Quantitative computed tomography measures of pectoralis muscle area and disease severity in chronic obstructive pulmonary disease. A cross-sectional study. *Ann Am Thorac Soc* 2014; 11: 326–334.
17. Molgat-Seon Y, Guler SA, Peters CM, et al. Pectoralis muscle area and its association with indices of disease severity in interstitial lung disease. *Respir Med* 2021; 186: 106539.
18. Rubin GD, Ryerson CJ, Haramati LB, et al. The role of chest imaging in patient management during the COVID-19 pandemic: a multinational consensus statement from the fleischner society. *Radiology* 2020; 296: 172–180.
19. Ufuk F, Demirci M, Sagtas E, et al. The prognostic value of pneumonia severity score and pectoralis muscle Area on chest CT in adult COVID-19 patients. *Eur J Radiol* 2020; 131: 109271.
20. Surov A, Kardas H, Besutti G, et al. Prognostic role of the pectoralis musculature in patients with COVID-19. *A Multicenter Study Acad Radiol*. DOI: [10.1016/j.acra.2022.05.003](https://doi.org/10.1016/j.acra.2022.05.003). Epub ahead of print 16 May 2022
21. Saillant NN. Chest wall anatomy. *Rib Fracture Management* 2018; 25–33.
22. Zu ZY, Jiang MD, Xu PP, et al. Coronavirus disease 2019 (COVID-19): a perspective from China. *Radiology* 2020; 296: E15–E25.
23. Pietro KM, Ricardo G, Rui GPND, et al. Relationship of pectoralis muscle area and skeletal muscle strength with exercise tolerance and dyspnea in interstitial lung disease. *Sarcoidosis Vasc Diffuse Lung Dis* 2017; 34: 200–208.
24. Shirahata T, Sato H, Yogi S, et al. The product of trunk muscle area and density on the CT image is a good indicator of energy expenditure in patients with or at risk for COPD. *Respir Res* 2021; 22: 18.
25. Kim YS, Kim EY, Kang SM, et al. Single cross-sectional area of pectoralis muscle by computed tomography - correlation with bioelectrical impedance based skeletal muscle mass in healthy subjects. *Clin Physiol Funct Imaging* 2017; 37: 507–511.
26. Nishimura JM, Ansari AZ, D'Souza DM, et al. Computed tomography-assessed skeletal muscle mass as a predictor of outcomes in lung cancer surgery. *Ann Thorac Surg* 2019; 108: 1555–1564.
27. Kim G, Kang SH, Kim MY, et al. Prognostic value of sarcopenia in patients with liver cirrhosis: a systematic review and meta-analysis. *PLoS One* 2017; 12: e0186990.
28. Alcazar J, Aagaard P, Haddock B, et al. Assessment of functional sit-to-stand muscle power: cross-sectional trajectories across the lifespan. *Exp Gerontol* 2021; 152: 111448.
29. Alcazar J, Alegre LM, Van Roie E, et al. Relative sit-to-stand power: aging trajectories, functionally relevant cut-off points, and normative data in a large European cohort. *J Cachexia, Sarcopenia Muscle* 2021; 12: 921–932.
30. von Elm E, Altman DG, Egger M, et al. The Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Int J Surg* 2014; 12: 1495–1499.
31. Chung M, Bernheim A, Mei X, et al. CT imaging features of 2019 Novel Coronavirus (2019-nCoV). *Radiology* 2020; 295: 202–207.
32. Li K, Fang Y, Li W, et al. CT image visual quantitative evaluation and clinical classification of coronavirus disease (COVID-19). *Eur Radiol* 2020; 30: 4407–4416.
33. Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987; 40: 373–383.
34. Tiedemann A, Lord SR, Sherrington C, et al. The development and validation of a brief performance-based fall risk assessment tool for use in primary care. *J Gerontol A Biol Sci Med Sci* 2010; 65: 896–903.
35. Morita AA, Bisca GW, Machado FVC, et al. Best Protocol for the Sit-to-Stand Test in Subjects With COPD. *Respir Care* 2018; 63: 1040–1049.
36. Alcazar J, Navarrete-Villanueva D, Mañas A, et al. 'Fat but powerful' paradox: association of muscle power and adiposity markers with all-cause mortality in older adults from the EXERNET multicentre study. *Br J Sports Med* 2021; 55: 1204–1211.
37. Cohen J. Statistical power analysis for the behavioral sciences. DOI: [10.4324/9780203771587](https://doi.org/10.4324/9780203771587). Epub Ahead of Print 2013.
38. Metter EJ, Talbot LA, Schrager M, et al. Arm-cranking muscle power and arm isometric muscle strength are independent predictors of all-cause mortality in men. *J Appl Physiol* 2004; 96: 814–821.
39. Piotrowicz K, Gąsowski J, Michel J-P, et al. Post-COVID-19 acute sarcopenia: pathophysiology and management. *Aging Clin Exp Res*. DOI: [10.1007/s40520-021-01942-8](https://doi.org/10.1007/s40520-021-01942-8). Epub Ahead of Print 30 July 2021.
40. Yoshiko A, Ogawa M, Shimizu K, et al. Chair sit-to-stand performance is associated with diagnostic features of sarcopenia in older men and women. *Arch Gerontol Geriatr* 2021; 96: 104463.
41. Arnal-Gómez A, Cebrià I, Iranzo MA, et al. Using updated EWGSOP2 definition diagnosing sarcopenia spanish old adults: clin approach. *J Clin Med Res*; 10. DOI: [10.3390/jcm10051018](https://doi.org/10.3390/jcm10051018). Epub ahead Print 2 March 2021.
42. Torres-Castro R, Solis-Navarro L, Sitjà-Rabert M, et al. Functional limitations Post-COVID-19: a comprehensive assessment strategy. *Arch Bronconeumol* 2021; 57: 7–8.
43. Pizarro-Pennarolli C, Sánchez-Rojas C, Torres-Castro R, et al. Assessment of activities of daily living in patients post COVID-19: a systematic review. *PeerJ* 2021; 9: e11026.
44. Torres-Castro R, Vasconcello-Castillo L, Alsina-Restoy X, et al. Respiratory function in patients post-infection by

- COVID-19: a systematic review and meta-analysis. *Pulmonology* 2021; 27: 328–337.
45. Núñez-Cortés R, Malhue-Vidal C, Gath F, et al. The impact of charlson comorbidity index on the functional capacity of COVID-19 survivors: a prospective cohort study with one-year follow-up. *Int J Environ Res Public Health* 2022; 19: 7473.
 46. Núñez-Cortés R, Ortega-Palavecinos M, Soto-Carmona C, et al. Social determinants of health associated with severity and mortality in patients with COVID-19. *Gac Med Mex* 2021; 157: 263–270.
 47. Rivera-Lillo G, Torres-Castro R, Fregonezi G, et al. Challenge for rehabilitation after hospitalization for COVID-19. *Arch Physical Medicine Rehabilitation* 2020; 101: 1470–1471.
 48. Barbat-Artigas S, Rolland Y, Vellas B, et al. Muscle quantity is not synonymous with muscle quality. *J Am Med Directors Assoc* 2013; 14: 852.e1–852.e7.