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Pro-Metrics

ORIGINAL RESEARCH

Covid-19 and Sarcopenia: A bibliometric analysis

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ABSTRACT

Objective. Covid-19 disease affects all organs of the human body, including muscles. However, the association between Covid-19 and Sarcopenia has not been analyzed bibliometrically. In this study, we performed a bibliometric analysis to identify the current hotspots and highlight future trends.

Design/Methodology/Approach. The Scopus database was used as a data source. We analyzed the following indicators: document type, country, collaboration patterns, affiliation, journal name, and citation patterns. MS-Excell and VOSviewer were employed to map and determine essential topics in this field.

Results/Discussion. 846 publications were retrieved from Scopus. They have received 15651 citations, averaging 18.5 citations per paper (CPP). 29.43% of publications received extramural funding from international agencies and together registered a CPP of 40.66. The USA published the most significant number of publications (n=162). However, the highest CPP and Relative Citation Index (RCI) was registered by China (186.0 and 10.05). "Medicine" contributed the largest global output share (82.98%). The *Sapienza Università di Roma,* Italy (n=20) was the most productive institution. Whereas, *Deutsches Zentrum für Herz-Kreislauf-Forschung e. V.* Germany registered the highest CPP and RCI. *F. Landi* was the most impactful author. The *International Journal of Environmental Research and Public Health* (n=38) and *Nutrients* (n=28) were the most productive journals. The most prevalent topics of research, as reflected in keywords by frequency of their appearance, were "Covid-19" (n=810), "Sarcopenia" (n=324), "Skeleton Muscle" (n=309), "Muscle Mass" (n=214), "Grip Strength" (n=199), "Physical Activity" (n=172).

Conclusions. This bibliometric study revealed that papers on 'Covid-19 and Sarcopenia" received a high number of citations (average of 18.5 CPP) within a short period. Those papers which got external funding received much higher CPP (40.66). Maximum contributory and impactful authors were from High-Income Countries. The highly cited papers were 5.25% of the total publications.

Keywords: sarcopenia; Covid-19; muscle; osteoporosis; bibliometrics.

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INTRODUCTION

The COVID-19 pandemic has presented numerous global challenges for the public and healthcare providers. COVID-19 is a multi-organ infectious disease characterized by a severe inflammatory and highly catabolic status, influencing the deep changes in the body build, especially the amount, structure, and function of skeletal muscles, which would amount to acutely developed Sarcopenia (Piotrowicz *et al.,* 2021). The documented risk factors for worse prognoses of COVID-19 cases have been identified, viz. older age and medical comorbid conditions like diabetes, obesity, and chronic lung and cardiovascular diseases (Sanyaolu *et al.,* 2020).

Sarcopenia is defined as a decline in skeletal muscle mass and function (strength (e.g., grip strength)) or performance (e.g., walking speed) (Malmstrom & Morley, 2013). Irwin Rosenberg first used the word 'sarcopenia' (Greek 'sarx' or flesh + 'penia' or loss) in 1989 to describe the age-related loss in lean muscle mass (Rosenberg, 1997). However, it was not until 2019 that Sarcopenia was officially recognized as a disease with its own ICD code (M62.84) (Vellas *et al.,* 2018). Sarcopenia has been reported to affect 5-13% of persons aged 60 to 70 years and up to 50% of people over 80 (von Haehling, 2010). Apart from aging, other possible causes for Sarcopenia include severe illness, critical care admission, poor nutrition, vitamin D deficiency, and inflammation (Remelli *et al.,* 2019; Robinson *et al.,* 2012)

Acute Sarcopenia (muscle insufficiency) is a recently recognized condition that has been defined by the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) as incident sarcopenia within six months following a stressful event (Cruz-Jentoft *et al.,* 2010). All types of sarcopenias are associated with poor health outcomes such as falls, cognitive impairment, depression, fractures (13), and increased mortality (Xia *et al.,* 2020). Although Sarcopenia is primarily a disease of the elderly, its development may be associated with conditions not exclusively seen in older persons, like disuse, malnutrition, and cachexia. Similar to osteopenia, it can also be seen in younger patients with inflammatory diseases (Schneider *et al.,* 2008). Muscle accounts for 60% of the body's protein stores. Muscle mass decrease is directly responsible for functional impairment, loss of strength, increased likelihood of falls, and loss of autonomy (Janssen, 2002; Ewans, 1995).

Sarcopenia is associated with poor outcomes in COVID-19 cases due to several reasons, like intensive care unit admission, the need for invasive mechanical ventilation, mortality, lengthy hospital stays, and poor rehabilitation. Chronic inflammation, immune dysfunction, respiratory muscle dysfunction, and swallowing dysfunction may be the underlying factors in these cases (Wang *et al.,* 2023).

In this study, we aim to study the following:

(i) overall characteristics and trends in this area by studying the type and source of literature, literature growth, and research impact, funding sources, and extent of international collaboration;
(ii) subject scatter of literature by broad and narrow sub-fields, including analysis of significant keywords;
(iii) contribution and citation impact of key players, including countries, organizations and authors and the collaborative linkages among them;
(iv) media of communications and bibliometric characteristics of high-cited publications.

METHODS

Using a comprehensive search strategy, all relevant publications on "Covid-19 and Sarcopenia" were identified and downloaded from the Scopus database covering the period from the origin of the Covid-19 until 25.4. 2023. The search strategy used a combination of keywords related to "Covid-19" and "Sarcopenia" identified from existing reviews appearing on this topic, which were searched in "Title-Abs-Key" and "Keyword" tags, as listed below. The search strategy was the following:

> (TITLE-ABS-KEY ("covid 19" OR "2019 novel coronavirus" OR "coronavirus 2019" OR "coronavirus disease 2019" OR "2019-novel CoV" OR "2019 nov" OR covid 2019 OR corvidae OR "corona virus 2019" OR ncov-2019 OR ncov2019 OR "nov 2019" OR 2019-ncov OR covid-19 OR "Severe acute respiratory syndrome coronavirus 2" OR "SARS-CoV-2") AND KEY (sarcopenia OR "skeletal muscle" OR "muscle mass" OR "grip strength" OR

"muscle quality" OR "intramuscular adipose tissue" OR "myosteatosis"))

The search yielded 846 publications, which were further analyzed as indicated in objectives using additional features of the Scopus database. The publications that received over 50 CPP were considered high-cited papers (HCP).

Microsoft Excel and VOSviewer software were used to analyze and visualize retrieved data. Keyword co-occurrence analysis was performed using both author and indexed keywords with the help of VOSviewer software. There was no restriction on language, document, or source type. Select quantitative and qualitative indicators were used to measure research performance in this area.

RESULTS

The global research output on "Covid-19 and Sarcopenia" consisted of 846 papers, increasing from 127 in 2020 to 291 in 2021 and 355 in 2022 and then declining to 73 in 2023 (due to partial coverage in 2023). These papers received 15651 citations, averaging 18.50 per paper (CPP). The maximum of these articles were research articles:493 (58.27%) and reviews-(184 (21.75%). The majority of these were published in English language (97.28%).

In 29.43% (249) of papers from more than 100 funding agencies, external funding was received. These funded papers together received 10125 citations, averaging 40.66 CPP. The primary external funding agencies supporting research in this area were the National Institutes of Health (n=35), Fundação de Amparo à Pesquisa do Estado de São Paulo (n=20), and Conselho Nacional de Desenvolvimento Científico e Tecnológico (n=19).

GEOGRAPHICAL DISTRIBUTION

Seventy-eight countries participated in global research on "Covid-9 and Sarcopenia", of which 50 contributed 1-10 papers each, 21 contributed 11-50 papers each, 5 contributed 51-100 papers each, and 2 contributed 147-162 papers each. The top 12 countries individually contributed 31 to 162 papers and together contributed 802 papers and 34296 citations, accounting for 94.8% and more than 100.0% share in global papers and citations. Among the top 12 countries, the top 4 countries contributed above the average productivity (66.83) of all nations: the USA (n=162), Italy (n=147), U.K. (n=69), and Brazil (n=68). Six countries registered higher CPP and RCI (42.76 and 2.31) of all nations: China (186.0 and 10.05), USA (55.91 and 3.02), Canada (54.91 and 2.97), Germany (42.23 and 2.82), France (51.34 and 2.78) and the U.K. (46.64 and 2.52). The international collaborative papers share of the top 12 countries varied from 16.0% to 61.36%, averaging 44.64% (Table 1).

No.	Country name	TP	TC	CPP	RCI	ICP	%ICP	TLS	TLS in map	Cluster	Cluster color
1	USA	162	9058	55.91	3.02	81	50.00	164	60	1	Red
2	Italy	147	3657	24.88	1.34	59	40.14	157	43	2	Green
3	U.K.	69	3218	46.64	2.52	34	49.28	123	57	1	Red
4	Brazil	68	1070	15.74	0.85	26	38.24	111	55	1	Red
5	Japan	55	952	17.31	0.94	29	52.73	81	45	1	Red
6	Germany	53	2768	52.23	2.82	30	56.60	90	37	2	Green
7	Spain	42	1455	34.64	1.87	22	52.38	113	57	2	Green
8	Turkey	50	298	5.96	0.32	8	16.00	34	27	3	Blue
9	France	44	2259	51.34	2.78	19	43.18	80	33	2	Green
10	Canada	44	2416	54.91	2.97	27	61.36	127	53	1	Red
11	China	37	6882	186.0	10.05	21	56.76	107	50	1	Red
12	India	31	263	8.48	0.46	12	38.71	80	50	3	Blue
Total of the top 12 countries		802	34296	42.76	2.31	358	44.64				
Global output		846	15651	18.5	1.00						
Share of top 12 countries in global output		94.8									

Table 1. Geographical distribution of papers by country. Note: TP: Total papers; TC: Total citations; CPP: Citations per paper; RCI: Relative citation index; ICP: International collaborative papers; TLS: Total link strength.

The total link strength (TLS) of the top 12 countries varied from 34 to 164, with the most significant number of collaborative linkages (n=164) depicted by the USA, followed by Italy (n=157) and Canada (n=127). The country-to-country linkages varied from 3 to 21, with the largest collaborative linkages (n=21) depicted by the country pair "USA and Italy," followed by "USA and Brazil" and "USA and China" (14 linkages each).

Clustering was done using the data of these twelve countries, which produced three clusters. The details of clusters, cluster color, links within these 12 countries, total links within the data set, number of papers, and total citations are given in Table 1. Figure 1 depicts the map of the collaboration network of the top twelve producers. The various clusters are: (i) Cluster 1 (Red, 6 countries) includes USA, U.K., Brazil, Japan, Canada, and China; (ii) Cluster 2 (Green, 4 countries) includes Italy, Germany, Spain, and France; and (iii) Cluster 3 (Blue, 2 countries) includes India and Turkey.

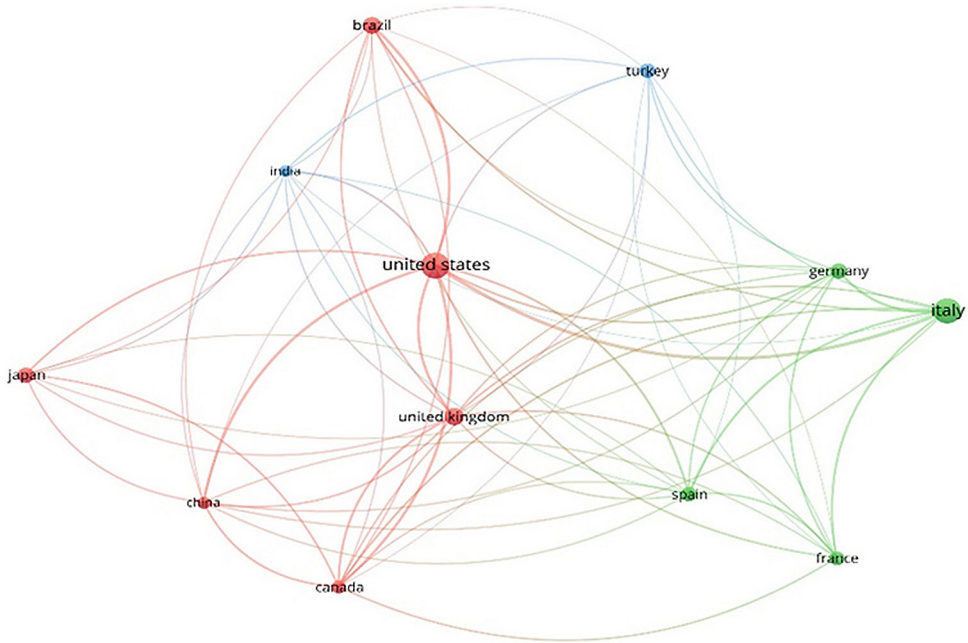

Figure 1. Collaboration network of top twelve countries (Software VOSviewer; N>30).

SUBJECT-WISE DISTRIBUTION

"Medicine" contributed the largest share (82.98%) in global output, followed by "Biochemistry Genetics & Molecular Biology" (22.10%) and "Neurosciences" (6.26%). In terms of citation impact, "Biochemistry Genetics & Molecular Biology" registered the highest CPP of 18.35, and "Environmental Science" had the least (5.49 CPP) (Table 2).

No.	Broad subject	TP	TC	CPP	%TP
1	Medicine	702	12199	17.38	82.98
2	Biochemistry Genetics & Molecular Biology	187	3432	18.35	22.10
3	Neurosciences	53	654	12.34	6.26
4	Agricultural & Biological Sciences	52	655	12.60	6.15
5	Environmental Science	41	225	5.49	4.85
6	Immunology & Microbiology	35	405	11.57	4.14
7	Pharmacology, Toxicology & Pharmaceutics	23	144	6.26	2.72
	Global output	846	15651	18.50	100.00

Table 2. Distribution of papers by broad subjects by Scopus classification.
Note: TP: Total papers; TC: Total citations; CPP: Citations per paper.

INSTITUTIONAL DISTRIBUTION

A total of 2102 organizations participated in global research on "Covid-19 and Sarcopenia". Of these, the top 30 organizations individually contributed 7-20 papers and together contributed 343 papers and 20584 citations, accounting for 50.54% and more than 100.0% share in global publications and citations.

Among the top 30 organizations, the top 12 organizations contributed above the average productivity (11.43) of all organizations. The topmost institutions were Sapienza Università di Roma, Italy (n=20), Universidade de São Paulo, Brazil (n=19), Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy (n=18), Charité – Universitätsmedizin Berlin, Germany (n=17), and Harvard Medical School, USA (n=16). Eight organizations registered above average CPP and RCI (60.01 and 3.24) of all organizations The international collaborative papers (ICP) share of the top 30 organizations varied from 9.09% to 91.67%, with an average of 45.77% (Table 3).

No.	Organization name	TP	TC	CPP	RCI	ICP	%ICP	TLS
1	Sapienza Università di Roma, Italy	20	134	6.70	0.36	10	50.00	77
2	Universidade de São Paulo, Brazil	19	750	39.47	2.13	10	52.63	106
3	Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy	18	400	22.22	1.20	7	38.89	85
4	Charité - Universitätsmedizin Berlin, Germany	17	2302	135.41	7.32	9	52.94	146
5	Harvard Medical School, USA	16	2177	136.06	7.35	10	62.50	192
6	Hacettepe Üniversitesi, Turkey	14	72	5.14	0.28	3	21.43	50
7	Università degli Studi di Milano, Italy	14	219	15.64	0.85	4	28.57	49
8	Brigham and Women's Hospital, USA	13	2205	169.62	9.17	7	53.85	104
9	Università Cattolica del Sacro Cuore, Campus di Roma, Italy	13	354	27.23	1.47	4	30.77	55
10	Berliner Institut für Gesundheitsforschung, Germany	13	2267	174.38	9.43	6	46.15	170
11	Università degli Studi di Padova, Italy	12	431	35.92	1.94	7	58.33	65
12	Karolinska Institutet, Sweden	12	1624	135.33	7.32	11	91.67	184
13	INSERM, France	11	245	22.27	1.20	3	27.27	65
14	Università Vita-Salute San Raffaele	11	170	15.45	0.84	1	9.09	48
15	IRCCS Ospedale San Raffaele	11	143	13.00	0.70	1	9.09	46
16	Instituto de Salud Carlos III, Spain	10	64	6.40	0.35	1	10.00	53
17	Università degli Studi di Palermo	10	233	23.30	1.26	6	60.00	64
18	Facoltà di Medicina e Odontoiatria	10	101	10.10	0.55	6	60.00	40
19	University of Alberta	9	2024	224.89	12.16	8	88.89	145
20	Københavns Universitet, Denmark	9	330	36.67	1.98	7	77.78	58
21	Deutsches Zentrum für Herz-Kreislauf-Forschung e. V.	9	2136	237.33	12.83	6	66.67	130
22	Istituti Clinici Scientifici Maugeri Spa – SB	9	60	6.67	0.36	3	33.33	27
23	Sorbonne Université, France	8	138	17.25	0.93	5	62.50	54
24	CNRS Centre National de la Recherche Scientifique	8	1643	205.38	11.10	4	50.00	137
25	Universidade Federal de São Paulo	8	76	9.50	0.51	6	75.00	34
26	University of Toronto	8	38	4.75	0.26	4	50.00	63
27	Università degli Studi di Napoli Federico II	8	24	3.00	0.16	3	37.50	23
28	Freie Universität Berlin	8	166	20.75	1.12	1	12.50	71
29	University of Health Sciences, Turkey	8	29	3.63	0.20	1	12.50	21
30	Johns Hopkins School of Medicine, USA	7	29	4.14	0.22	3	42.86	60
	Total of the top 30 organizations	343	20584	60.01	3.24	157	45.77	2422
	Global output	846	15651	18.50	1.00			
		40.54						

Table 3. Bibliometric profile of top 30 most productive organizations. Note: TP: Total papers; TC: Total citations; CPP: Citations per paper; RCI: Relative citation index; ICP: International collaborative papers; TLS: Total link strength.

The TLS of the top 30 organizations individually varied from 21 to 192, with the highest collaborative linkages (n=192) reported by Harvard Medical School, USA, followed by Karolinska Institutet, Sweden (n=184), and Berliner Institut für GesundheitsforschungGermany (n=170). Organization pairs reported the highest bilateral collaborative linkages (13) "Berliner Institut für Gesundheitsforschung, Germany, and Charité – Universitätsmedizin Berlin, Germany," "Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy and Università Cattolica del Sacro Cuore, Campus di Roma, Italy" (12 linkages each), and "Sapienza Università di Roma, Italy, and Facoltà di Medicina e Odontoiatria".

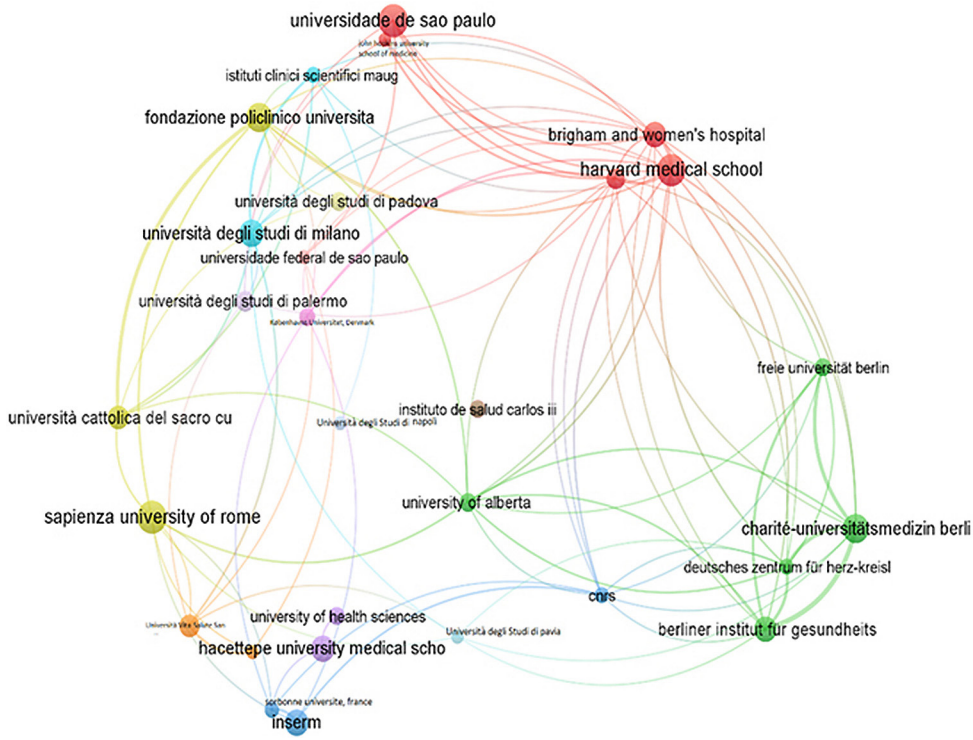

Figure 2. Cluster map of top 30 institutions (Software: VOSviewer; n>6).

From the 2102 organizations, the 30 top producers were selected to study collaboration and collaboration patterns among themselves. Figure 2 presents a cluster map of these institutions. The VOSviewer software produced 7 clusters having two to five members, as described below:

- Cluster 1 (Red, 5 organizations) includes Universidade de São Paulo, Brazil; Harvard Medical School, USA; Brigham and Women's Hospital, USA; Karolinska Institutet and Johns Hopkins School of Medicine, USA;
- Cluster 2 (Green, 5 organizations) includes Charité - Universitätsmedizin Berlin, Germany, Berliner Institut für Gesundheitsforschung, Germany, University of Alberta, Deutsches Zentrum für Herz-Kreislauf-Forschung e. V. and Freie Universität Berlin;
- Cluster 3 (Blue, 3 organizations) includes INSERM, France, Sorbonne Université, France, and CNRS Centre National de la Recherche Scientifique;
- Cluster 4 (Yellow, 3 organizations) includes Sapienza Università di Roma, Italy; Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy and Università Cattolica del Sacro Cuore, Campus di Roma, Italy;
- Cluster 5 (Violet, 2 organizations) includes Hacettepe Üniversitesi, Turkey, and the University of Health Sciences, Turkey;
- Cluster 6 (Turquoise, 2 organizations) includes Università degli Studi di Milano, Italy, and Istituti Clinici Scientifici Maugeri Spa – SB;
- Cluster 7 (Orange, 2 organizations) includes Università Vita-Salute San Raffaele and IRCCS Ospedale San Raffaele.

AUTHORS DISTRIBUTION

The 5386 authors participated in global research on "Covid-19 and Sarcopenia". The top 30 authors individually contributed 1-10 papers and together contributed 145 papers and received 2206 citations. Among the top 30 authors, 14 were from Italy, four from Denmark, two from Japan, Germany, and the USA, and one from Egypt, Israel, and Spain.

Among the top 30 organizations, the top 15 authors contributed above the average productivity (4.83) of all organizations, with F. Landi (n=10), M. Kara (n=8), M. Cesari, E. Marzetti and L. Ozcakar (n=7 each) at the top (Table 4).

#	Author name	Author affiliation	TP	TC	CPP	RCI	ICP	%ICP	TLS
1	Landi, F.	Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy	10	90	9.00	0.49	4	40.00	116
2	Kara, M.	Hacettepe Üniversitesi, Turkey	8	68	8.50	0.46	1	12.50	18
3	Cesari, M.	Università degli Studi di Milano, Italy	7	59	8.43	0.46	4	57.14	26
4	Marzetti, E.	Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy	7	280	40.00	2.16	3	42.86	117
5	Özçakar, L.	Hacettepe Üniversitesi, Turkey	7	64	9.14	0.49	1	14.29	17
6	Azzolino, D.	Università degli Studi di Milano	6	45	7.50	0.41	3	50.00	25
7	Ekiz, T.	Türkmenbaşı Medical Center, Turkey	5	60	12.00	0.65	1	20.00	13
8	Arai, H.	National Center for Geriatrics and Gerontology, Japan	5	104	20.80	1.12	1	20.00	51
9	Barazzoni, R.	Università degli Studi di Trieste, Italy	5	147	29.40	1.59	5	100.00	61
10	Calvani, R.	Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy	5	19	3.80	0.21	1	20.00	279
11	Ciciarello, F	Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy	5	19	3.80	0.21	1	20.00	180
12	Galluzzo, V.	Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy	5	19	3.80	0.21	1	20.00	179
13	Muscaritoli, M.	Sapienza Università di Roma, Italy	5	15	3.00	0.16	1	20.00	56
14	Tankisi, H.	Aarhus Universitetshospital, Denmark	5	75	15.00	0.81	1	20.00	51
15	Tosato, M.	Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy	5	19	3.80	0.21	1	20.00	178
16	Ali, A. M.	National Center of Neurology and Psychiatry Kodaira, Egypt	4	114	28.50	1.54	4	100.00	7
17	Amato, A. A.	Brigham and Women's Hospital, USA	4	93	23.25	1.26	0	0.00	11
18	Carraro, U.	Università degli Studi di Padova, Italy	4	16	4.00	0.22	4	100.00	19
19	Cuerda, C.	Hospital General Universitario Gregorio Marañon, Spain	4	84	21.00	1.14	3	75.00	89
20	Harbo, T.	Aarhus Universitetshospital, Denmark	4	75	18.75	1.01	0	0.00	46
21	Laviano, A.	Sapienza Università di Roma, Italy	4	71	17.75	0.96	4	100.00	44
22	Lavie, C. J.	Ochsner Health System, USA	4	469	117.25	6.34	1	25.00	10
23	Picca, A.	Fondazione Policlinico Universitario Agostino Gemelli IRCCS	4	10	2.50	0.14	0	0.00	168
24	Savera, G.	Fondazione Policlinico Universitario Agostino Gemelli IRCCS	4	16	4.00	0.22	1	25.00	168
25	Singer, P.	Tel Aviv University	4	96	24.00	1.30	3	75.00	54
26	Surov, A.	Martin-Universität Halle-Wittenberg, Germany	4	11	2.75	0.15	2	50.00	45
27	Wienke, A.	Martin-Universität Halle-Wittenberg, Germany	4	11	2.75	0.15	2	50.00	47
29	Yamamoto, K.	Osaka University Graduate School of Medicine, Osaka	4	37	9.25	0.50	0	0.00	23
30	Agergaard, J.	Odense Universitetshospital, Denmark	3	20	6.67	0.36	0	0.00	44
			145	2206	15.21	0.82	53	36.55	2142
		Global output	846	15651	18.50	1.00		0.00	
			17.14	14.09				0.00	

Table 4. Bibliometric profile of top 30 most productive authors. Note: TP: Total papers; TC: Total citations; CPP: Citations per paper; RCI: Relative citation index; ICP: International collaborative papers; TLS: Total link strength.

The TLS of the top 30 authors individually varied from 21 to 192, with the highest collaborative linkages (n=279) reported by R. Calvani, followed by F. Ciciarello (N=180) and v. Galluzzo (n=179) (Table 4). The author-to-author collaboration linkages varied from 1 to 6. The highest bilateral collaborative linkages (7) were reported by author pair "M. Kara and L. Ozcakar," followed by author pair "M. Cesari and D. Azzolino" and "F. Landi and E. Marzetti" (6 linkages each).

Figure 3 provides the author's network of the 36 authors with 3 or more papers, as obtained through VOSviewer. The co-author networking was carried out for 36 authors with 3 or more papers. These 36 authors were clustered into various clusters. The authors included in various clusters are as follows: Cluster 1 (Red, 7 authors) includes F Landi, E. Marzetti, R. Calvani, F. Ciciarello, V. Galluzzo, C.M. Prado and M. Tosato; Cluster 2 (Green, 5 authors) includes R. Barazzoni, M. Muscaritoli, C. Cuerda, A. Laviano and P. Singer; Cluster 3 (Blue, 3 authors) includes H. Tankisi, H. Aandersen and T. Harbo; Cluster 4 (Yellow, 3 authors) includes M. Kara, I. Ozcakar and T. Ekiz; Cluster 5 (Violet, 2 authors) includes M. Cesari and D. Azzolino; Cluster 6 (Light Blue, 2 authors) includes E.M. De Silva and C. Tanaka; and Cluster 7 (Orange, 2 authors) includes A. Sarov and A. Wienke.

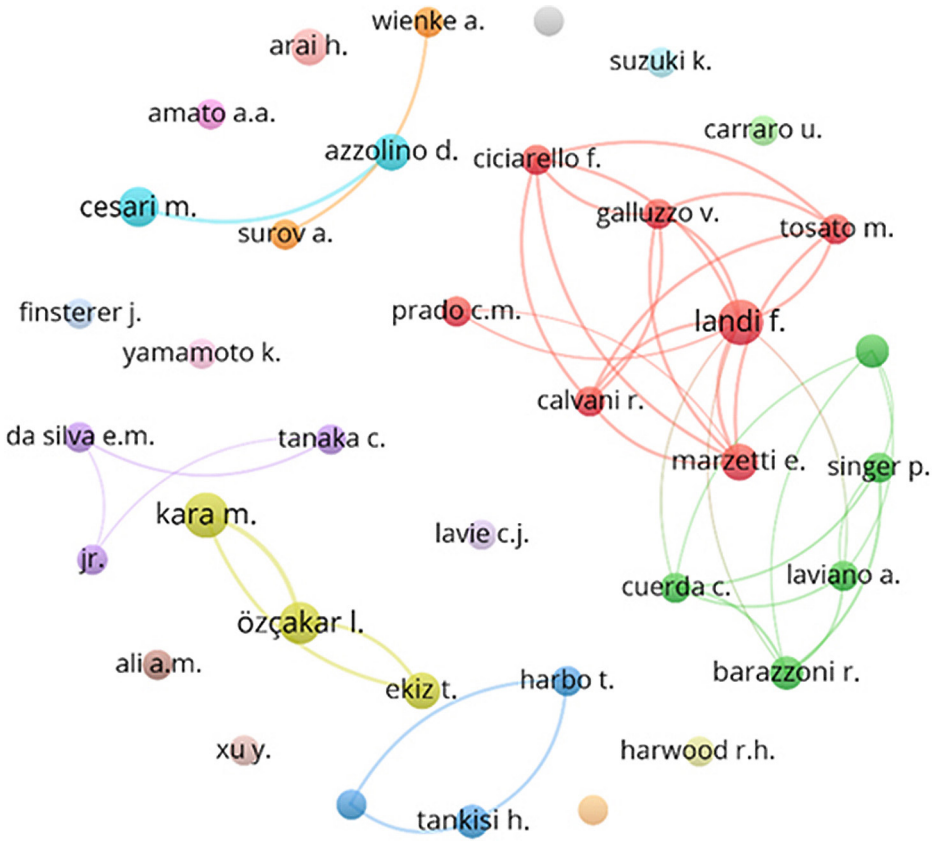

Figure 3. Top 35 authors network on "Covid-19 and Sarcopenia" (Software VOSviewer; N>3).

JOURNALS DISTRIBUTION

Among the 846 papers, 844 were published in journals and 2 in book series. The top 6 most productive journals were: International Journal of Environmental Research and Public Health (n=38), Nutrients (n=28), Clinical Nutrition (n=18), Journal of Cachexia Sarcopenia and Muscle (n=17), Clinical Nutrition Espen (n=14), and International Journal of Molecular Sciences (n=13). The top 6 journals in terms of CPP were PLOS One (28.4), Clinical Neurophysiology (25.6), ERJ Open Research (24.5), Critical Care (24.20), Medical Hypotheses 21.67) and Aging Clinical and Experimental Research (20.25) (Table 5).

No.	Journal name	TP	TC	CPP	%TP
1	International Journal of Environmental Research and Public Health	38	219	5.76	4.50
2	Nutrients	28	475	16.96	3.32
3	Clinical Nutrition	18	234	13.00	2.13
4	Journal Of Cachexia Sarcopenia and Muscle	17	283	16.65	2.01
5	Clinical Nutrition Espen	14	201	14.36	1.66
6	International Journal of Molecular Sciences	13	192	14.77	1.54
7	European Journal Of Translational Myology	9	57	6.33	1.07
8	Frontiers In Nutrition	9	29	3.22	1.07
9	Aging Clinical and Experimental Research	8	162	20.25	0.95
10	Frontiers In Physiology	8	65	8.13	0.95
11	BMJ Open	7	21	3.00	0.83
12	Experimental Gerontology	7	36	5.14	0.83
13	Frontiers In Immunology	7	54	7.71	0.83
14	Geriatrics And Gerontology International	7	100	14.29	0.83
15	Age And Ageing	6	4	0.67	0.71
16	Clinics In Geriatric Medicine	6	22	3.67	0.71
17	Journal Of Clinical Medicine	6	32	5.33	0.71
18	Journal Of Personalized Medicine	6	29	4.83	0.71
19	Journal Of The American Medical Directors Association	6	105	17.50	0.71
20	Medical Hypotheses	6	130	21.67	0.71
21	Clinical Neurophysiology	5	128	25.60	0.59
22	Critical Care	5	121	24.20	0.59
23	European Journal Of Internal Medicine	5	30	6.00	0.59
24	Frontiers In Endocrinology	5	32	6.40	0.59
25	Frontiers In Medicine	5	18	3.60	0.59
26	Journal Of Nutrition Health And Aging	5	34	6.80	0.59
27	Plos One	5	142	28.40	0.59
28	Diabetes And Metabolic Syndrome Clinical Research And Reviews	4	79	19.75	0.47
29	Diagnostics	4	14	3.50	0.47
30	ERJ Open Research	4	98	24.50	0.47
		273	3146	11.52	32.35
		844			
		32.35			

Table 5. Bibliometric profile of top 30 most productive journals.
Note: TP: Total papers; TC: Total citations; CPP: Citations per paper.

CO-WORD ANALYSIS

In total, 2212 keywords were isolated from 846 publications on this topic, with frequencies ranging from one to 824. From these author keywords, we have identified 55 most significant keywords, with the frequency of occurrences ranging from 27 to 814 listed in Table 6. The leading keywords by their frequency of co-occurrence were: “Covid-19”(n=814), “Sarcopenia” (n=324), “Skeletal Muscle” (n=309), “Muscle Mass”(n=214), “Grip Strength”(n=199), “Physical Activity”(n=172), “Muscle Strength”(n=162), “Exercise”(n=159), “Body Mass” (n=142), “Obesity”(n=140), etc.

The co-occurrence network of 55 selected significant keywords was visualized and clustered in Figure 4 to discover the theme clusters indicated in various colors. According to the cluster results in VOSViewer, as Figure 3 shows five clusters that vary in size and are represented by various colors were identified. The selected clusters and their associated keywords are as follows:

- Cluster 1 (Red, 14 keywords) includes hypertension, comorbidity, inflammation, diabetes mellitus, virus pneumonia, c. reactive protein, cardiovascular disease, interleukin 6, immune response, adult respiratory distress syndrome, chronic obstructive lung disease, angiotensin-converting enzyme 2, biological marker, tumor necrosis factor, and respiratory failure;
- Cluster 2 (Green, 15 keywords) includes Grip Strength, Physical Activity, Muscle Strength, Exercise, Fatigue, Dyspnea, Depression, Hand Strength, Long Covid, Physical Performance, Physiotherapy, Cognitive Defect, Rehabilitation, Aerobic Exercise, and Anxiety;
- Cluster 3 (Blue, 9 keywords) includes muscle mass, body mass, obesity, body composition, malnutrition, nutritional status, body weight loss, fat mass, and adipose tissue;
- Cluster 4 (Yellow, 8 keywords) includes covid-19, skeleton muscle, metabolism, muscle weakness, muscle atrophy, myalgia, myopathy, and myositis;
- Cluster 5 (Violet, 7 keywords) includes sarcopenia, frailty, aging, muscle function, vitamin D, physical inactivity, and practice guidelines

Rank	Keyword	Cluster	Cluster Color	Links Cluster	Links Total	Papers
1	covid-19	4	Green	54	4240	814
2	Sarcopenia	5	Violet	54	1866	324
3	skeletal muscle	4	Yellow	54	1540	309
4	muscle mass	3	Blue	54	1354	214
5	grip strength	2	Green	53	1188	199
6	physical activity	2	Green	54	1286	172
7	muscle strength	2	Green	54	1152	162
8	Exercise	2	Green	54	1161	159
9	body mass	3	Blue	54	1044	142
10	Obesity	3	Blue	54	1105	140
11	body composition	3	Blue	53	777	111
12	Frailty	5	Violet	53	677	101
13	Aging	5	Violet	53	651	98
14	Malnutrition	3	Blue	54	689	97
15	Fatigue	2	Green	53	752	93
16	Hypertension	1	Red	54	738	90
17	Comorbidity	1	Red	54	592	81
18	Inflammation	1	Red	54	629	79
19	Metabolism	4	Yellow	53	466	79
20	nutritional status	3	Blue	52	577	78
21	diabetes mellitus	1	Red	54	609	72
22	Dyspnea	2	Green	52	516	69
23	virus pneumonia	1	Red	52	415	67
24	muscle weakness	4	Yellow	51	464	65
25	c reactive protein	1	Red	54	496	64
26	Depression	2	Green	50	514	63
27	cardiovascular disease	1	Red	50	521	62
28	hand strength	2	Green	47	410	61
29	muscle atrophy	4	Yellow	54	425	59
30	long covid	2	Green	50	439	58
31	Myalgia	4	Yellow	51	417	56
32	physical performance	2	Green	50	420	53
33	body weight loss	3	Blue	54	427	52
34	interleukin 6	1	Red	53	411	49
35	muscle function	5	Violet	53	411	49
36	Physiotherapy	2	Green	47	310	46

Rank	Keyword	Cluster	Cluster Color	Links Cluster	Links Total	Papers
37	immune response	1	Red	49	325	45
38	adult respiratory distress syndrome	1	Red	49	292	42
39	chronic obstructive lung disease	1	Red	50	316	42
40	cognitive defect	2	Green	50	308	42
41	angiotensin converting enzyme 2	1	Red	47	306	40
42	Rehabilitation	2	Green	51	251	39
43	vitamin d	5	Violet	54	331	39
44	fat mass	3	Blue	44	280	38
45	biological marker	1	Red	48	246	37
46	adipose tissue	3	Blue	42	235	37
47	tumor necrosis factor	1	Red	50	298	36
48	nutritional assessment	3	Blue	46	276	36
49	aerobic exercise	2	Green	52	310	35
50	Anxiety	2	Green	48	283	34
51	physical inactivity	5	Violet	50	281	34
52	respiratory failure	1	Red	49	225	33
53	Myopathy	4	Yellow	40	212	33
54	practice guideline	5	Violet	48	235	33
55	Myositis	4	Yellow	45	185	27

Table 6. List of 55 significant keywords on "Covid-19 and Sarcopenia".

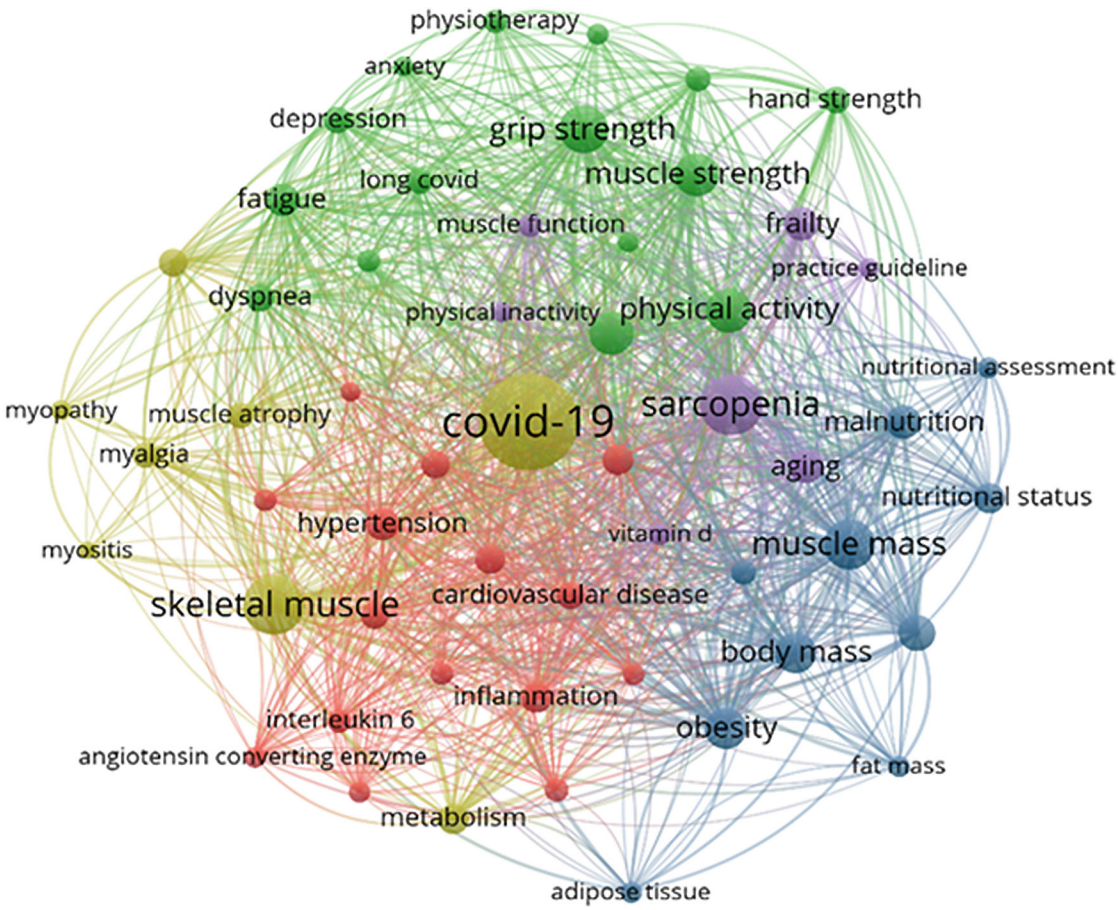

Figure 4. Cluster network of keywords for Covid-19 and Sarcopenia (Software VOSviewer; n>26).

HIGH-CITED PAPERS

The 44 HCP (5.2%) received 51 to 4168 citations, averaging 242.36 CPP. More than 100 CPP was achieved by 16 of these papers. The leading countries contributing to these HCPs were: the USA (n=15), Italy (n=12), and Germany (n=8). The original research articles (n=20) and the review articles (n=13) were majorly involved in the HCP list. Among 44 HCPs, 8 papers had the participation of one organization (i.e., zero collaborative), and 36 were involved in the participation of 2 or more organizations (17 - national collaboration, and 19 - international collaboration). Among 44 HCPs, 192 organizations and 446 authors participated. Among participating organizations, the largest number of papers (4 each) were contributed by Charité – Universitätsmedizin Berlin, Germany and Berliner Institut für Gesundheitsforschung, Germany, followed by Universidade de São Paulo, Brazil (3), and Brigham and Women's Hospital, USA (3). Thirty-seven journals participated in the 44 HCPs, of which the maximum no of three papers was contributed by Clinical Nutrition, followed by two papers each by JAMA Neurology, Nutrients (2).

DISCUSSION AND CONCLUDING REMARKS

The relationship between Sarcopenia and COVID-19 has received substantial interest in the current literature. There has been a notable global increase in Covid-19-related publications since the beginning of the pandemic and sarcopenia-related research. As a result, many scholars have conducted bibliometric studies on both global Covid-19 (Gupta *et al.,* 2021; Fan et al, 2020) and international sarcopenia research (Suzan *et al.,* 2020; Vaishya *et al.,* 2022; Yuan *et al.,* 2022; Yang *et al.,* 2020; Yang *et al.,* 2023; Wu *et al.,* 2022; Xiao *et al.,* 2022). However, there is no bibliometric study has yet been done on "Covid-19 and Sarcopenia", despite an increase in publications and reviews (Ying *et al.,* 2022; Wang *et al.,* 2023; Xu *et al.,* 2022; Aryana, 2022) in this area. We, therefore, carried out a bibliometric study in this field for the first time.

We identified 846 publications on the theme in Scopus from 2020 to 2023. The study identified 55 significant keywords from publications and important research areas on this topic using keyword co-occurrences methodology. It was observed that 846 publications on this topic registered 15651 citations, with an average of 18.5 CPP. External funding was received by 29.43% of total publications, which depicted a much higher citation impact per paper of 40.66. Therefore, there is a need to explore additional funding sources so that various organizations can conduct better research.

Among 68 participating countries on this topic, the top 12 accounts for 94.8% and over 100.0% share in global papers and citations. All the top countries belonged to high-income-countries (HIC) category. The USA (n=162) led in terms of publication productivity, followed by Italy (n=147), the U.K. (n=69), and Brazil (n=68). Whereas China (186.0 and 10.05), the USA (55.91 and 3.02), Canada (54.91 and 2.97) and lead in terms of CPP and RCI. From the publication data, it was observed that only a few countries are actively participating. We suggest that the governments in various nations need to identify active organizations working on the impact of Covid-19 and encourage them to work in this area by supporting them through adequate workforce and financial resources.

The average share of international collaborative papers (ICP) of the top 12 countries varied from 16.0% to 61.36%, with an average of 44.64%. The largest share of ICP in total output was reported by Canada (61.36%), followed by China (56.76%) and Japan (52.73%). It is observed that international collaboration needs to be enhanced to achieve more productive and qualitative results.

Recognizing the leading organizations and authors in the research field is necessary so that the funding agencies and international collaborators can approach them for future tie-ups. The top most productive organizations were Sapienza Università di Roma, Italy (n=20), Universidade de São Paulo, Brazil (n=19), Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Italy (n=18), Charité – Universitätsmedizin Berlin, Germany (n=17), and Harvard Medical School, USA (n=16). However, the most impactful organizations were Deutsches Zentrum für Herz-Kreislauf-Forschung e. V., Germany (237.33 and 12.83), University of Alberta, Canada (224.89 and 12.16), CNRS Centre National de la Recherche Scientifique, France (205.38 and 11.10), Berliner Institut für Gesundheitsforschung, Germany (174.38 and

9.43) and Brigham and Women's Hospital, USA (169.62 and 9.17), as per their impact measured by CPP, and RCI. A more even distribution in author productivity was observed compared to institutional productivity. Despite 5386 authors participating in global research on this topic, only the top 30 authors account for 17.14% and 14.09% share in global publications and citations. The most productive authors were F. Landi (n=10), M. Kara (n=8), M. Cesari, and E. Marzetti, in contrast to C.J. Lavie (117.25 and 6.34), E. Marzetti (40.0 and 2.16), R. Barazzoni (29.40 and 1.59) and A.M. Ali (28.50 and 1.54) depicting a much higher CPP, and RCI.

Regarding citation impact (measured by citation frequency), 44 papers (5.2%) registered 51 to 4168 CPP. These HCPs were published by the authors from the HIC, like the USA (n=15), Italy (n=12), Germany (n=8), China, Spain, and the U.K. (n=7 each), and organizations such as Charité – Universitätsmedizin Berlin, Germany and Berliner Institut für Gesundheitsforschung, Germany (n=4), followed by Universidade de São Paulo, Brazil (3), Brigham and Women's Hospital, USA (3).

This study has revealed that the publications on "Sarcopenia and COVID-19" have drawn sufficient research interest in a short period (between Dec. 2019 and April 2023), and these research articles have drawn a substantial number of citations. The authors and institutions from HIC were significant contributors to this field. We suggest more research from Lower-Income-Middle Countries (LMIC), where a large global population was affected by the COVID-19 pandemic.

Conflict of Interest

None of the authors have any conflict of interest to disclose related to this research.

Contribution statement

RV: Concept, Literature search, Manuscript writing and Editing, Final reading, and approval.

BMG: Conceptualization, Data curation, and analysis, Manuscript writing and editing, Final reading approval.

YS: Data curation, and analysis, Final reading approval.

BMG: Investigation, methodology, writing-original draft and project administration, Final reading, and approval.

AV: Literature search, Manuscript writing, Editing, Final reading, and approval.

Statement of data consent

The data generated during the development of this study has been included in the manuscript.

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