Bibliometric analysis of the top-50 cited articles on COVID-19 and physical activity

Fan Zhang1, Ying Zhang2, Yaqi Yu3, Wei Lu4* and Huachun Zhang4*

1Department of Nephrology, Longhua Hospital Shanghai University of Traditional Chinese Medicine, Shanghai, China; 2Department of Surgery, Longhua Hospital Shanghai University of Traditional Chinese Medicine, Shanghai, China; 3Department of Cancer, Longhua Hospital Shanghai University of Traditional Chinese Medicine, Shanghai, China; 4Department of Nursing, Longhua Hospital Shanghai University of Traditional Chinese Medicine, Shanghai, China

Background: Since the 2019 novel coronavirus (COVID-19) pneumonia outbreak in late 2019, an endless stream of research has emerged surrounding physical activity. This study analyzes the 50 most influential articles on COVID-19 and physical activity over the past 2 years to describe the research landscape and hotspots from bibliometric citation analysis.

Methods: The top-50 cited articles were extracted from the Web of Science Core Collection database, and bibliometric citation analysis was performed by Excel 2019 and VOSviewer software.

Results: The top-50 articles were cited 160.48 ± 106.90 (range: 70–587). Most of the articles were from the United States (14), followed by Italy (11) and England (9). The International Journal of Environmental Research and Public Health (n = 10) is the journal with the top-50 cited articles. The collaboration between authors was mainly among three teams, including Smith L, Musumeci G, and Napoli C. The hotspot of research around COVID-19 and physical activity focused on lifestyle change (sedentary behavior, sitting time), mental health (depressive, anxiety, loneliness), the credibility of physical activity assessment tools (reliability, validity), and physical activity of different populations (gender, youth, children).

Conclusions: Based on a bibliometric analysis of high-impact articles on COVID-19 and physical activity highlights physical activity as an essential lifestyle change and developments and hotspots in this field. These data will provide insights for future researchers regarding the direction of physical activity research in the COVID-19 pandemic.

Keywords: COVID-19, physical activity, bibliometric analysis, citation classics, top-50
Introduction

2019 novel coronavirus (COVID-19), first reported in December 2019 in Wuhan, China, by a patient with pneumonia (1), has surpassed Middle East respiratory syndrome coronavirus and severe acute respiratory syndrome coronavirus in terms of transmission in the population (2). As of April 10, 2022, nearly 500 million confirmed cases of COVID-19, including 6.2 million deaths, have been reported in China and at least 85 other countries and/or regions (3). The human health risks of COVID-19 include direct harm to the respiratory system, damage to the immune system, worsening of the underlying disease, and ultimately systemic failure and death (4–6).

The COVID-19 outbreak turned the life of people around the world upside down (7–9). During the COVID-19 pandemic, not only were large numbers of patients hospitalized, but tens of thousands of people were forced into isolation in limited spaces (10). This dramatic change in lifestyle caused by immobilization (hospitalization and bed rest), isolation, and lack of physical activity could result in the second wave of attacks on the health and wellbeing of both infected and general populations (11–14). In this context, scholars from various countries have conducted a series of studies on COVID-19 and physical activity, addressing the role and impact of physical activity during the COVID-19 pandemic from different perspectives (15–17).

A citation is an article (citation) that cites another article (cited citation) as a reference. The number of citations is not only a measure of an article’s impact on the scientific community but is also the basis for generating a journal’s impact factor (IF) (18). Eugene Garfield introduced the term “citation classics” in 1955 to identify the most cited scientific articles in the Institute for Scientific Information (ISI) Web of Knowledge (now known as Web of Science) database (19). In most fields, an article cited more than 100 times is considered a citation classic (19). Reviewing the most cited articles (the so-called “citation classics”) can provide interesting information about scientific progress and research trends in a particular subject area (20).

Given that the publication of COVID-19 and physical activity is rapidly evolving, its scientific dynamics and profile deserve to be observed. Therefore, the primary objective of this review is to identify the 50 most-cited articles in the field of COVID-19 with physical activity based on a forward citation analysis, and the secondary objective is to visualize countries, authors, and keywords through VOSviewer software to increase the understanding of the current status of research and hot spots to inform the study priorities in the field.

Abbreviations: COVID-19, 2019 novel coronavirus.

Materials and methods

Search strategy

We selected the Web of Science Core Collection database as the publication source. The database encompasses more than 20,000 peer-reviewed, high-quality scholarly journals, including open access journals published in more than 250 medical, social science, and humanities disciplines worldwide, and is widely used for bibliometric analysis. In addition, the database provides the authors, countries, and keywords for each publication, which was necessary for this study (21). Since COVID-19 broke out in December 2019, our search dates are set for January 1, 2020, to April 9, 2022.

The search formula was TS = (“COVID-19” OR “SARS-CoV-2” OR “2019-nCoV” OR “2019 coronavirus” OR “2019 novel coronavirus”) AND TS = (“physical activity” OR “sedentary behaviors” OR “sedentary lifestyle” OR “physical inactivity” OR “sedentary time” OR “step per day” OR “steps per day” OR “step count” OR “step/day” OR “steps/day” OR “step/d” OR “steps/d” OR “daily step” OR “daily steps” OR “accelerometer” OR “pedometer”).

Publication selection and data extraction

First, the document type was restricted to “article” from the 2,310 publications initially retrieved, and then the title and abstract of each article were independently reviewed by two authors to ensure they were relevant to COVID-19 and physical activity. Then the top-50 cited articles were selected for bibliometric analysis based on the citation number sorting with 50 as the cut-off value. Our study had no restrictions on study population, design, or language. When non-English publications were encountered, we used DeepL for translation. The flow chart of the study is shown in Figure 1.
### TABLE 1 List of the top-50 cited articles.

| Author (year) | Title | Journal | Total citations | Average per year | References |
|---------------|-------|---------|-----------------|------------------|------------|
| Ammar et al. (22) | Effects of COVID-19 Home Confinement on Eating Behavior and Physical Activity: Results of the ECLB-COVID19 International Online Survey | Nutrients | 587 | 195.67 | (22) |
| Di Renzo et al. (23) | Eating habits and lifestyle changes during COVID-19 lockdown: an Italian survey | Journal of Translational Medicine | 471 | 157 | (23) |
| Stanton et al. (24) | Depression, Anxiety and Stress during COVID-19: Associations with Changes in Physical Activity, Sleep, Tobacco and Alcohol Use in Australian Adults | International Journal of Environmental Research and Public Health | 423 | 141 | (24) |
| Shechter et al. (25) | Psychological distress, coping behaviors, and preferences for support among New York healthcare workers during the COVID-19 pandemic | General Hospital Psychiatry | 339 | 113 | (25) |
| Moore et al. (26) | Impact of the COVID-19 virus outbreak on movement and play behaviors of Canadian children and youth: a national survey | International Journal of Behavioral Nutrition and Physical Activity | 294 | 98 | (26) |
| Pieh et al. (27) | The effect of age, gender, income, work, and physical activity on mental health during coronavirus disease (COVID-19) lockdown in Austria | Journal of Psychosomatic Research | 291 | 97 | (27) |
| Maugeri et al. (28) | The impact of physical activity on psychological health during COVID-19 pandemic in Italy | Heliyon | 263 | 87.67 | (28) |
| Lesser and Nienhuis (29) | The Impact of COVID-19 on Physical Activity Behavior and Well-Being of Canadians | International Journal of Environmental Research and Public Health | 223 | 74.33 | (29) |
| Dunton et al. (30) | Early effects of the COVID-19 pandemic on physical activity and sedentary behavior in children living in the US | BMC Public Health | 213 | 71 | (30) |
| Lebel et al. (31) | Elevated depression and anxiety symptoms among pregnant individuals during the COVID-19 pandemic | Journal of Affective Disorders | 205 | 68.33 | (31) |

(Continued)
| Author (year)           | Title                                                                 | Journal                                         | Total citations | Average per year | References |
|------------------------|----------------------------------------------------------------------|-------------------------------------------------|-----------------|------------------|------------|
| Huckins et al. (32)    | Mental Health and Behavior of College Students During the Early Phases of the COVID-19 Pandemic: Longitudinal Smartphone and Ecological Momentary Assessment Study | Journal of Medical Internet Research            | 196             | 65.33            | (32)       |
| Nguyen et al. (33)     | People with Suspected COVID-19 Symptoms Were More Likely Depressed and Had Lower Health-Related Quality of Life: The Potential Benefit of Health Literacy | Journal of Clinical Medicine                     | 194             | 64.67            | (33)       |
| Hamer et al. (34)      | Lifestyle risk factors, inflammatory mechanisms, and COVID-19 hospitalization: A community-based cohort study of 387,109 adults in UK | Brain Behavior and Immunity                      | 184             | 61.33            | (34)       |
| Meyer et al. (35)      | Changes in Physical Activity and Sedentary Behavior in Response to COVID-19 and Their Associations with Mental Health in 3052 US Adults | International Journal of Environmental Research and Public Health | 172             | 57.33            | (35)       |
| Robinson et al. (36)   | Obesity, eating behavior and physical activity during COVID-19 lockdown: A study of UK adults | Appetite                                        | 171             | 85.5             | (36)       |
| Zachary et al. (37)    | Self-quarantine and weight gain related risk factors during the COVID-19 pandemic | Obesity Research & Clinical Practice             | 161             | 53.67            | (37)       |
| Mattioli et al. (38)   | Quarantine during COVID-19 outbreak: Changes in diet and physical activity increase the risk of cardiovascular disease | Nutrition Metabolism and Cardiovascular Diseases | 158             | 52.67            | (38)       |
| Newby et al. (39)      | Acute Mental Health Responses During the COVID-19 Pandemic in Australia | PLoS One                                       | 153             | 51               | (39)       |
| Narici et al. (40)     | Impact of sedentarism due to the COVID-19 home confinement on neuromuscular, cardiovascular and metabolic health: Physiological and | European Journal of Sport Science               | 148             | 49.33            | (40)       |
| Author (year)        | Title                                                                 | Journal                                                                 | Total citations | Average per year | References |
|---------------------|----------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------|-----------------|------------|
| Zhang et al. (41)   | Mental Health Problems during the COVID-19 Pandemics and the Mitigation Effects of Exercise: A Longitudinal Study of College Students in China | International Journal of Environmental Research and Public Health       | 145             | 48.33           | (41)       |
| Sepulveda-Loyola et al. (42) | Impact of Social Isolation Due to COVID-19 on Health in Older People: Mental and Physical Effects and Recommendations | Journal of Nutrition Health & Aging                                      | 143             | 47.67           | (42)       |
| Carroll et al. (43) | The Impact of COVID-19 on Health Behavior, Stress, Financial and Food Security among Middle to High Income Canadian Families with Young Children | Nutrients                                                               | 140             | 46.67           | (43)       |
| Constandt et al. (44) | Exercising in Times of Lockdown: An Analysis of the Impact of COVID-19 on Levels and Patterns of Exercise among Adults in Belgium | International Journal of Environmental Research and Public Health       | 138             | 46              | (44)       |
| Barker-Davies et al. (45) | The Stanford Hall consensus statement for post-COVID-19 rehabilitation | British Journal of Sports Medicine                                       | 137             | 45.67           | (45)       |
| Gornicka et al. (46) | Dietary and Lifestyle Changes During COVID-19 and the Subsequent Lockdowns among Polish Adults: A Cross-Sectional Online Survey PLifeCOVID-19 Study | Nutrients                                                               | 131             | 43.67           | (46)       |
| Pecanha et al. (47) | Social isolation during the COVID-19 pandemic can increase physical inactivity and the global burden of cardiovascular disease | American Journal of Physiology-Heart and Circulatory Physiology         | 131             | 43.67           | (47)       |
| Deschasaux-Tanguy et al. (48) | Diet and physical activity during the coronavirus disease 2019 (COVID-19) lockdown (March-May 2020): results from the French NutriNet-Sante cohort study | American Journal of Clinical Nutrition                                 | 127             | 63.5            | (48)       |

(Continued)
| Author (year) | Title | Journal | Total citations | Average per year | References |
|--------------|-------|---------|-----------------|------------------|------------|
| Castaneda-Babarro et al. (49) | Physical Activity Change during COVID-19 Confinement | International Journal of Environmental Research and Public Health | 125 | 41.67 | (49) |
| Mattioli et al. (50) | COVID-19 pandemic: the effects of quarantine on cardiovascular risk | European Journal of Clinical Nutrition | 125 | 41.67 | (50) |
| Sallis et al. (51) | Physical inactivity is associated with a higher risk for severe COVID-19 outcomes: a study in 48 440 adult patients | British Journal of Sports Medicine | 115 | 57.5 | (51) |
| Sanchis-Gomar et al. (52) | Obesity and Outcomes in COVID-19: When an Epidemic and Pandemic Collide | Mayo Clinic Proceedings | 114 | 38 | (52) |
| Majumdar et al. (53) | COVID-19 pandemic and lockdown: cause of sleep disruption, depression, somatic pain, and increased screen exposure of office workers and students of India | Chronobiology International | 105 | 35 | (53) |
| Flanagan et al. (54) | The Impact of COVID-19 Stay-At-Home Orders on Health Behaviors in Adults | Obesity | 101 | 33.67 | (54) |
| Schmidt et al. (55) | Physical activity and screen time of children and adolescents before and during the COVID-19 lockdown in Germany: a natural experiment | Scientific Reports | 101 | 33.67 | (55) |
| Cheval et al. (56) | Relationships between changes in self-reported physical activity, sedentary behavior and health during the coronavirus (COVID-19) pandemic in France and Switzerland | Journal of Sports Sciences | 99 | 33 | (56) |
| Galle et al. (57) | Understanding Knowledge and Behaviors Related to COVID-19 Epidemic in Italian Undergraduate Students: The EPICO Study | International Journal of Environmental Research and Public Health | 92 | 30.67 | (57) |
| Yamada et al. (58) | Effect of the COVID-19 Epidemic on Physical Activity in Community-Dwelling Older | Journal of Nutrition Health & Aging | 91 | 30.33 | (58) |

(Continued)
| Author (year) | Title | Journal | Total citations | Average per year | References |
|--------------|-------|---------|-----------------|-----------------|------------|
| Bates et al. (59) | Adults in Japan: A Cross-Sectional Online Survey | Children-Basel | 90 | 30 | (59) |
| Carter et al. (60) | Considerations for Obesity, Vitamin D, and Physical Activity Amid the COVID-19 Pandemic | Obesity | 87 | 29 | (60) |
| Lopez-Bueno et al. (61) | Health-Related Behaviors Among School-Aged Children and Adolescents During the Spanish COVID-19 Confinement | Frontiers in Pediatrics | 86 | 28.67 | (61) |
| Romero-Blanco et al. (62) | Physical Activity and Sedentary Lifestyle in University Students: Changes during Confinement Due to the COVID-19 Pandemic | International Journal of Environmental Research and Public Health | 81 | 27 | (62) |
| Van Rheenen et al. (63) | Mental health status of individuals with a mood disorder during the COVID-19 pandemic in Australia: Initial results from the COLLATE project | Journal of Affective Disorders | 80 | 26.67 | (63) |
| Schuch et al. (64) | Associations of moderate to vigorous physical activity and sedentary behavior with depressive and anxiety symptoms in self-isolating people during the COVID-19 pandemic: A cross-sectional survey in Brazil | Psychiatry Research | 79 | 26.33 | (64) |
| Pillay et al. (65) | Nowhere to hide: The significant impact of coronavirus disease 2019 (COVID-19) measures on elite and semi-elite South African athletes | Journal of Science and Medicine in Sport | 79 | 26.33 | (65) |
| Gupta et al. (66) | Changes in sleep pattern and sleep quality during COVID-19 lockdown | Indian Journal of Psychiatry | 75 | 25 | (66) |
| Gallo et al. (67) | The Impact of Isolation Measures Due to COVID-19 | Nutrients | 75 | 25 | (67) |

(Continued)
The 50 most cited articles were reviewed, and the following information was extracted: (1) author; (2) year of publication; (3) journal; (4) impact factor (2021); (5) total citations; (6) annual citations.

**Visualization**

All information and data for each article are inserted into Microsoft Excel 2019 and VOSviewer (version 1.6.15). VOSviewer is a Java-based bibliometric networks analysis software, mainly for literature data, applicable to unimodal undirected network, focusing on the visualization of scientific knowledge. Co-authorship analysis is used to depict author and country collaboration. Co-occurrence analysis of keywords is performed to detect research hotspots.

**Statistical analysis**

Data are presented by using descriptive statistic and no statistical significance tests were performed.

**Result**

The 50 most cited articles in COVID-19 and physical activity research and the number of citations are shown in Table 1. The number of citations ranged from 70 to 587 (mean 160.48 ± 106.90; median: 131) and the annual citations ranged from 24.33 to 195.67 (mean 55.34 ± 35.48; median: 45.84).

The top-50 cited articles were published by authors from 34 countries (as shown in Figure 2) regarding country distribution. The United States contributed the highest number of articles (14), followed by Italy (11), England (9), Canada (8), and Spain (8). Figure 3 depicts the collaboration between the countries/regions that published the 50 most influential articles, showing close cooperation between a few countries and regions.

The 50 most cited articles were published in 34 journals with IF ranging from 1.759 to 13.800 (mean 4.55±2.17; median: 4.06) (Table 2). The International Journal of Environmental Research and Public Health (n = 10) is the journal with the most top-50 cited articles.

From the perspective of co-authorship, the collaboration network analysis divided authors into three clusters, identifying several major research teams, including Smith L, Musumeci G, and Napoli C (as shown in Figure 4).
Based on the keywords co-occurrence (Figure 5), the network mapping showed that the hotspots of research around COVID-19 and physical activity mainly focused on lifestyle change (sedentary behavior, sitting time), mental health (depressive, anxiety, loneliness), the credibility of physical activity assessment tools (reliability, validity), and physical activity of different populations (gender, youth, children).

Discussion

Isolation at home during the prevalence of COVID-19 may prevent the virus from spreading but, in turn, brings a sedentary lifestyle (62). In terms of non-communicable disease prevention, physical activity is likely to be important for everyone, so it is more critical during outbreaks and blockades (72). Research around COVID-19 and physical activity has been gaining attention since the novel coronavirus outbreak in late 2019. This study describes the countries, journals, authors, and keywords of high-impact articles in this research area through citation analysis, showing the current trends.

The number of citations in this study was much lower than other physical activity-related citations, such as aging (73) and sleep (74) research. A major reason was the shorter duration. In addition, we extracted the average number of citations per year for different articles. This value can be used as a proxy for the total number of citations to assess the current impact of an article (75). The highest total citation was published in *Nutrients* in 2020 by Ammar et al. (22), which designed “Effects of home Confinement on multiple Lifestyle Behaviors during the COVID-19 outbreak (ECLB-COVID19)” Electronic survey, with 1,047 responses reflecting an increase in sitting time from 5 to 8 h per day due to home isolation, and this article also had the highest annual citations.

Nearly 1/3 of the 50 most cited articles were from the United States, which can be attributed to (1) the tendency of researchers in the United States to prioritize citing their national sources when publishing articles (76), and (2) the fact that the United States is the country with the highest number of confirmed novel coronavirus pneumonia since the 2019 outbreak (77) and has invested abundant scientific funding. Unfortunately, COVID-19 broke out in Wuhan, China, but there are only two highly cited articles from China, including the Taiwan region.

An analysis of the co-authors of the top-50 cited articles showed that the authors who contributed to the study of COVID-19 and physical activity were mainly the team of Smith L, Musumeci G, and Napoli C. Their findings focused on (1) the association between changes in physical activity and mental status before and after the COVID-19 outbreak (35, 61, 64); (2) the effects of the COVID-19 pandemic on physical activity in different populations (28, 69); and (3) changes in physical activity induced by COVID-19 in college students (57, 68), which provided a great reference value for the subsequent studies in this field.

This study found that most articles were published in high-impact (≥3) journals, such as the *British Journal of Sports Medicine* and the *International Journal of Behavioral Nutrition and Physical Activity*, a sports medicine journal. Notably, the top-50 cited articles were published in a wide variety of journals, including public health (e.g., *International Journal of Environmental Research and Public Health*), psychology (e.g., *General Hospital Psychiatry*), nutrition (e.g., *American Journal of Clinical Nutrition*), and neurology (e.g., *Brain Behavior and Immunity*), and general journals (e.g.,
Scientific Reports, PLoS One), indicating that research on physical activity during the COVID-19 pandemic is a typically multidisciplinary intersection.

We also found that most studies focused on epidemic-induced changes in physical activity in different populations, the effect of physical activity on mental status, and the association between poor lifestyle habits and COVID-19. Understanding the different research areas of the top-50 cited articles is crucial, as it is crucial not only for journal editors to select and judge future scientific work but also for young researchers to publish effectively. Surprisingly, almost all the studies on the list were investigative studies, with fewer intervention studies addressing physical activity promotion during the COVID-19 pandemic. This may be related to the focus of earlier researchers on exploring potential factors for changing lifestyle habits. Considering the benefits of physical activity for the COVID-19 and general populations, the future trend will gradually shift to high-quality randomized controlled trials. Recently published guidelines provided general recommendations on physical activity, focusing on exercise training guidelines for isolated homes due to COVID-19 (78–80).

We performed a co-occurrence analysis of keywords in the top-50 cited articles by VOSviewer to describe the research hotspots based on the citation analysis. The network mapping showed that the focus around COVID-19 and physical activity was on (1) the lifestyle changes caused by the epidemic remained a hotspot; (2) the impact of the epidemic on residents’ mental health (including depressive, anxiety, loneliness), especially the longitudinal trends, remained a direction to be explored; (3) the physical activity levels of different populations in the COVID-19 context, mainly for youth and children, but also cannot ignore the elderly and chronic disease population; (4) reliability and validity of different instruments in measuring physical activity changes, and assessment of physical activity by more accurate and objective accelerometers may be the future trend; (5) exercise-based physical activity for post-COVID. As Jimeno-Almazán et al. stated, "Exercise has been shown to be beneficial in multiple pathologies with which the post-COVID-19 syndrome shares similarities both in terms of symptoms and its possible pathogenic mechanisms, it is worth considering the potential favorable effect that this would bring in the recovery of these patients" (81).
This study has implications for public health. First, reducing exercise and other physical activity due to the blockade policy of the outbreak may have potentially adverse effects on the physical and mental health of children and adolescents, and the resumption of physical activity by young people should be promoted after COVID-19 (82). Second, a sedentary lifestyle is potentially a significant cause of cardiovascular disease, the leading cause of death. The outbreak of COVID-19 may worsen this situation because isolation decreases habitual and recreational physical activity. Therefore, Crisafulli and Pagliaro suggest that jogging alone (wearing a mask) could gradually increase when the epidemic improves (i.e., when the prevalence and increase of new cases are significantly reduced) (83). Third, frailty is a common condition in the elderly and chronically ill populations, and physical inactivity can exacerbate the worsening of frailty (84). In the dual context of the epidemic and healthy aging, policymakers should pay more attention to the physical activity management in these two vulnerable groups.

The present study has a strength in that, based on 50 classical citations, it is more worthwhile for researchers to analyze the hot spots of research on COVID-19 and physical activity. Inevitably, there are also some limitations. First, the databases in our study were limited to the Web of Science Core Collection, resulting in the absence of other “classic” articles. Second, we did not analyze...
Authors Cooperation Network Mapping.

Keyword co-occurrence analysis.
inter-institutional collaborations, which may have reduced the contribution. The third limitation is the inherent bias of citation analysis. The total citations may increase over time, which means that older publications will undoubtedly receive more citations than newer ones (85).

Conclusion

This study analyzed the 50 most cited articles on COVID-19 and physical activity through bibliometric citation analysis. The results provide a landscape of physical activity research in global outbreaks of novel coronaviruses and identify substantial progress.

Data availability statement

The original contributions presented in the study are included in the article supplementary material; further inquiries can be directed to the corresponding author/s.

Author contributions

FZ and WL: conception and design. YY and YZ: collection data. FZ: manuscript writing. WL and HZ: manuscript revise. All authors had read and approved the final manuscript and agreed on its submission.

Funding

This study was supported by the Longhua Hospital Shanghai University of Traditional Chinese Medicine (Grant No. Y21026) and Shanghai University of Traditional Chinese Medicine (Grant No. 2022YJ-10).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher’s note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Pan A, Liu L, Wang C, Guo H, Hao X, Wang Q, et al. Association of public health interventions with the epidemiology of the COVID-19 outbreak in Wuhan, China. JAMA. (2020) 323:1915–23. doi: 10.1001/jama.2020.6130

2. Meo SA, Alhowi AM, Al-Khala T, Meo IM, Hafez DM, Isqbal M, et al. Novel coronavirus 2019-nCoV: prevalence, biological and clinical characteristics comparison with SARS-CoV and MERS-CoV. Eur Rev Med Pharmacol Sci. (2020) 24:2012–9. doi: 10.26355/eurrev_202002_20379

3. World Meters. COVID-19 Coronavirus Pandemic. Available online at: https://www.worldometers.info/coronavirus/

4. Yao XH, Luo T, Shi Y, He ZC, Tang R, Zhang PP, et al. A cohort autopsy study defines COVID-19 systemic pathogenesis. Cell Res. (2021) 31:836–46. doi: 10.1038/s41422-021-00523-8

5. Haudebourg AE, Perier F, Tuftel S, de Prost N, Razaz K, Mekontso Dessap A, et al. Respiratory mechanics of COVID-19- versus non-COVID-19-associated acute respiratory distress syndrome. Am J Respir Crit Care Med. (2020) 202:287–90. doi: 10.1164/rccm.202004-1226LE

6. Richardson S, Hirsch JS, Narasimhan M, Crawford JM, McGinn T, Davidson KW, et al. Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City area. JAMA. (2020) 323:2052-9. doi: 10.1001/jama.2020.6775

7. Balanzá-Martínez V, Atienza-Carbonell B, Kapczinski F, De Boni RB. Lifestyle behaviours during the COVID-19 time to connect. Acta Psychiatr Scand. (2020) 141:399–400. doi: 10.1111/aps.14177

8. Giuntella O, Hyde K, Saccardo S, Sadoff S. Lifestyle and mental health disruptions during COVID-19. Proc Natl Acad Sci USA. (2021) 118:e2016632118. doi: 10.1073/pnas.2016632118

9. Xiang M, Zhang Z, Kowalha K. Impact of COVID-19 pandemic on children and adolescents' lifestyle behavior larger than expected. Prog Cardiovasc Dis. (2020) 63:531–2. doi: 10.1016/j.pcad.2020.04.013

10. Woods JA, Hutchinson NT, Powers SK, Roberts WO, Gomes-Cabrera MC, Radak Z, et al. The COVID-19 pandemic and physical activity. Sports Med Health Sci. (2020) 2:55–64. doi: 10.1016/j.smhs.2020.05.006

11. Burtscher J, Burtscher M, Millet GP. (Indoor) isolation, stress, and physical inactivity: Vicious circles accelerated by COVID-19? Scand J Med Sci Sports. (2020) 30:1544–5. doi: 10.1111/sms.13706

12. Fancourt D, Steptoe A, Bu F. Trajectories of anxiety and depressive symptoms during enforced isolation due to COVID-19 in England: a longitudinal observational study. Lancet Psychiatry. (2021) 8:141–9. doi: 10.1016/S2215-0366(20)30482-X

13. Hellewell J, Abbott S, Gimma A, Bosse NI, Jarvis CI, Russell TW, et al. Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts. Lancet Glob Health. (2020) 8:e488–96. doi: 10.1016/S2214-109X(20)30174-7

14. Hwang TJ, Rabheru K, Peisah C, Reichman W, Ikeda M. Loneliness and social isolation during the COVID-19 pandemic. Int Psychogeriatr. (2020) 32:1217–29. doi: 10.1017/S104161022000988

15. Caputo EL, Reichert FF. Studies of physical activity and COVID-19 during the pandemic: a scoping review. J Phys Act Health. (2020) 17:1275–84. doi: 10.1123/jpah.2020.0406

16. Carvalho VO, Gois CO. COVID-19 pandemic and home-based physical activity. J Allergy Clin Immunol Pract. (2020) 8:2833–4. doi: 10.1016/j.jaip.2020.05.018

17. Dwyer MJ, Pasini M, De Dominis S, Righi E. Physical activity: benefits and challenges during the COVID-19 pandemic. Scand J Med Sci Sports. (2020) 30:1291–4. doi: 10.1111/sms.13710

18. Hirsch JE. An index to quantify an individual's scientific research output. Proc Natl Acad Sci USA. (2005) 102:16569–72. doi: 10.1073/pnas.0507655102
21. Zhang F, Ye J, Bai Y, Wang H, Wang W. Exercise-Based rehabilitation: a bibliometric analysis from 1969 to 2021. Front Med. (2022) 9:842919. doi: 10.3389/fmed.2022.842919

22. Ammar A, Brach M, Trabelsi K, Chtourou H, Boukhrais O, Massoudi L, et al. Effects of COVID-19 quarantine confinement on eating behavior and physical activity: results of the ECLB-COVID19 international online survey. Nutrients. (2020) 12:1583. doi: 10.3390/nu12061583

23. Di Renzo I, Gualtieri P, Pivari F, Soldati L, Attina A, Cinnelli G, et al. Eating habits and lifestyle changes during COVID-19 lockdown: an Italian survey. J Transl Med. (2020) 18:229. doi: 10.1186/s12967-020-02399-5

24. Stanton R, To QG, Khalesi S, Williams SL, Alleye SJ, Thwaite TL, et al. Depression, anxiety and stress during COVID-19: associations with changes in physical activity, sleep, tobacco and alcohol use in Australian adults. Int J Environ Res Public Health. (2020) 17:4065. doi: 10.3390/ijerph17114065

25. Shechter A, Diaz F, Moise N, Anstey DE, Ye SQ, Agarwal S, et al. Psychological distress, coping behaviors, and preferences for support among New York healthcare workers during the COVID-19 pandemic. Gen Hosp Psychiatry. (2020) 65:1-13. doi: 10.1016/j.genhosppsych.2020.06.007

26. Moore SA, Faulkner G, Rhodes RE, Brussoun M, Chulak-Borzer T, Ferguson LJ, et al. Impact of the COVID-19 virus outbreak on movement and play behaviours of Canadian children and youth: a national survey. Int J Behav Nutr Phys Act. (2020) 17:85. doi: 10.1186/s12966-020-00987-8

27. Pieh C, Budimir S, Probst T. The effect of age, gender, income, work, and physical activity on mental health during coronavirus disease (COVID-19) lockdown in Austria. J Psychosom Res. (2020) 136:110186. doi: 10.1016/j.jpsychores.2020.110186

28. Maugeri G, Castrogiovanni P, Battaglia G, Pippi R, D`Agata V, Palma A, et al. The impact of physical activity on psychological health during COVID-19 pandemic in Italy. Helv心通脳mens. (2020) 114:101351. doi: 10.1016/j.githem.2020.08.015

29. Lesser IA, Nienhuis CP. The impact of COVID-19 on physical activity behavior and well-being of Canadians. Int J Environ Res Public Health. (2020) 17:3899. doi: 10.3390/ijerph17113899

30. Dunton GF, Do B, Wang SD. Early effects of the COVID-19 pandemic on physical activity and sedentary behavior in children living in the US. BMC Public Health. (2020) 20:1351. doi: 10.1186/s12889-020-04929-3

31. Lebel C, MacKinnon A, Baghavate M, Tomfohr-Madsen L, Giesbrecht G. Elevated depression and anxiety symptoms among pregnant individuals during the COVID-19 pandemic: A J Affet Disord. (2020) 277:5-13. doi: 10.1016/j.jad.2020.07.126

32. Hucksin JF, deSiva AW, Wang WC, Hedlund E, Rogers C, Nepal SK, et al. Mental health and behavior of college students during the early phases of the COVID-19 pandemic: longitudinal smartphone and ecological momentary assessment study. JMIR Internet Res. (2020) 22:e20185. doi: 10.2196/20185

33. Nguyen HC, Nguyen MH, Do BN, Tran CQ, Nguyen TTP, Pham KM, et al. People with suspected COVID-19 symptoms were more likely depressed and had lower health-related quality of life: the potential benefit of health literacy. J Clin Med. (2020) 9:6651. doi: 10.3390/jcm9040665

34. Hamer M, Kivimaki M, Gale CR, Batty GD. Lifestyle risk factors, inflammatory mechanisms, and COVID-19 hospitalization: a community-based cohort study of 387,109 adults in UK. Brain Behav Immun. (2020) 87:184–7. doi: 10.1016/j.bbi.2020.05.059

35. Meyer J, McDowell C, Lansing J, Brower C, Smith L, Tully M, et al. Changes in physical activity and sedentary behavior in response to COVID-19 and their associations with mental health in 3022 US adults. Int J Environ Res Public Health. (2020) 17:6469. doi: 10.3390/ijerph17061469

36. Robinson E, Boyland E, Chisholm A, Harrold J, Maloney NG, Marty L, et al. Relationships between changes in self-reported physical activity, sedentary behaviour and health during the coronavirus (COVID-19) pandemic in France and Switzerland. J Sports Sci. (2021) 39:669–704. doi: 10.1080/02640414.2020.1841396

37. Gallo F, Sabella EA, Da Molin G, De Giglio O, Caggiano G, Di Onofrio V, et al. Understanding knowledge and behaviors related to COVID-19 epidemic in Italian undergraduate students: the EPICO study. Int J Environ Res Public Health. (2020) 17:3481. doi: 10.3390/ijerph17103481
Sedentary behaviors and physical activity of Italian undergraduate students during COVID-19 pandemic brings a sedentary lifestyle in young adults: a Sustainability study.

Coronavirus disease (2019) measures on elite and semi-elite South African athletes. Dijkstra HP, et al. Nowhere to hide: the significant impact of coronavirus disease (2019) on behaviors across the 24-hour day in children and adolescents: physical activity, sedentary behavior, and sleep. Children. (2020) 7:138. doi: 10.3390/children7090138

Carter SJ, Bananawaski MN, Fly AD. Considerations for obesity, vitamin d, and physical activity amid the COVID-19 pandemic. Obesity. (2020) 28:1176–7. doi: 10.1002/oby.22838

Lopez-Bueno R, Lopez-Sanchez GE, Casasius JA, Calatayud J, Gil-Salmeron A, Grabovac I, et al. Health-Related behaviors among school-aged children and adolescents during the spanish Covid-19 confinement. Front Pediatr. (2020) 8.573. doi: 10.3389/fped.2020.00573

Romero-Blanco C, Rodriguez-Almagro J, Onieva-Zafría MD, Parra-Fernandez ML, Prado-Laguna MD, Hernandez-Martinez A. Physical activity and sedentary lifestyle in university students: changes during confinement due to the COVID-19 pandemic. Int J Environ Res Public Health. (2020) 17:6567. doi: 10.3390/ijerph17186567

Van Rheenen TE, Meyer D, Neill E, Phlipoups A, Tan EJ, Toh WL, et al. Mental health status of individuals with a mood-disorder during the COVID-19 pandemic in Australia: initial results from the COLLATE project. J Affect Disord. (2020) 275:69–77. doi: 10.1016/j.jad.2020.06.037

Schuch FB, Bulzinge RA, Meyer J, Vancampfort D, Firth J, Stubbs B, et al. Associations of moderate to vigorous physical activity and sedentary behavior with depressive and anxiety symptoms in self-isolating people during the COVID-19 pandemic: a cross-sectional survey in Brazil. Psychiatry Res. (2020) 292:113339. doi: 10.1016/j.psychres.2020.113339

Pillay L, van Rensburg D, van Rensburg AJ, Ramagole DA, Holtzhausen L, Djulstra HP, et al. Nowhere to hide: the significant impact of coronavirus disease 2019 (COVID-19) measures on elite and semi-South African athletes. J Sci Med Sport. (2020) 23:670–9. doi: 10.1016/j.jsams.2020.05.016

Gupta R, Grover S, Basu A, Krishnan V, Tripathi A, Subramaniam A, et al. Changes in sleep pattern and sleep quality during COVID-19 lockdown. Indian J Psychiatry. (2020) 62:370–8. doi: 10.4103/psychiatry.IndianJPsychiatry.523_20

Gallo LA, Gallo TF, Young SL, Morritz KM, Akison LK. The impact of isolation measures due to COVID-19 on energy intake and physical activity levels in Australian university students. Nutrients. (2020) 12:1865. doi: 10.3390/nu12061865

Galle F, Sabella EA, Ferracuti S, De Giglio O, Caggiano G, Protanio C, et al. Sedentary behaviors and physical activity of Italian undergraduate students during lockdown at the time of CoViD-19 pandemic. Int J Environ Res Public Health. (2020) 17:6171. doi: 10.3390/ijerph17116171

Giustino V, Parroco AM, Gennaro A, Musumeci G, Palma A, Battaglia G. Physical activity levels and related energy expenditure during COVID-19 quarantine among the sicilian active population: a cross-sectional online survey study. Sustainability. (2020) 12:4556. doi: 10.3390/su12114556

Zheng C, Huang WY, Sheridan S, Sit CH, Chen XK, Wong SH. COVID-19 pandemic brings a sedentary lifestyle in young adults: a cross-sectional and longitudinal study. Int J Environ Res Public Health. (2020) 17:6035. doi: 10.3390/ijerph17166035

Tornese G, Geconi V, Monasta L, Carletti C, Faleschini E, Barbi E. Glycemic control in type 1 diabetes mellitus during COVID-19 quarantine and the role of in-home physical activity. Diabetes Technol Ther. (2020) 22:462–7. doi: 10.1089/dia.2020.0169

Bauman AE, Reis RS, Sallis JF, Wells JC, Loos R, Martin BW. Correlates of physical activity: why are some people physically active and others not? Lancet. (2012) 380:258–71. doi: 10.1016/S0140-6736(12)60735-1

Müller AM, Assari P, Ebrahim NA, Khosh S. Physical activity and aging research: a bibliometric analysis. J Aging Phys Act. (2016) 24:476–83. doi: 10.1123/japa.2015-0188

Memon AR, Vandelanotte C, Olds T, Duncan MJ, Vincent GE. Research combining physical activity and sleep: a bibliometric analysis. Percept Mot Skills. (2012) 125:154–81. doi: 10.1177/00315125114099780

Kim HJ, Yoon DY, Kim ES, Lee K, Bae JS, Lee JH. The 100 most-cited articles in neuroimaging: a bibliometric analysis. Neuroimage. (2016) 139:149–56. doi: 10.1016/j.neuroimage.2016.06.029

Link AM. US and non-US submissions: an analysis of reviewer bias. JAMA. (1998) 280:246–7. doi: 10.1001/jama.280.3.246

Coronavirus Resource Center. COVID-19 dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU). Coronavirus Resource Center. Available online at: https://coronavirus.jhu.edu/map.html

da Silveira MP, da Silva Fagundes KK, Bizuti MR, Starck E, Rossi RC, de Resende ES. Physical exercise as a tool to help the immune system against COVID-19: an integrative review of the current literature. Clin Exp Med. (2021) 21:12–28. doi: 10.1007/s12288-020-00650-3

Khoramipour K, Baserhi A, Hekmatiak AA, Castell L, Ruber RT, Suzuki K. Physical activity and nutrition guidelines to help with the fight against COVID-19. J Sports Sci. (2021) 39:101–7. doi: 10.1080/02640414.2020.1807089

Polero P, Rebollo-Seco C, Adsuar JC, Pérez-Gómez J, Rojo-Ramos J, Manzano-Redondo F, et al. Physical activity recommendations during COVID-19: narrative review. Int J Environ Res Public Health. (2021) 18:5329. doi: 10.3390/ijerph18105329

Jimeno-Almazán A, Pallarés JG, Buendia-Romero Á, Martínez-Cava A, Franco-López F, Sánchez-Alcaraz Martínez B, et al. Post-COVID-19 syndrome and the potential benefits of exercise. Int J Environ Res Public Health. (2021) 18:5329. doi: 10.3390/ijerph18105329

Catalaerràs G, Fonos V, Cataldi L, Cugusi L, Crisafulli A, Bassareo PP. Need for resuming sports and physical activity for children and adolescents following COVID-19 infection. Sport Sci Health. (2021) 8:573. doi: 10.3389/fspst.2021.609119

Crisafulli A, Pagliaro P. Physical activity/inactivity and COVID-19. Eur J Prev Cardiol. (2020) 28:e24–6. doi: 10.1177/2047487320927597

Clegg A, Young J, Iliffe S, Rücker MO, Rockwood K. Frailty in elderly people. Lancet. (2013) 381:752–62. doi: 10.1016/S0140-6736(12)62167-9

Pepe A, Kurtz MJ. A measure of total research impact independent of time and discipline. PLoS ONE. (2012) 7:e46428. doi: 10.1371/journal.pone.0046428