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# Global trends and future prospects of COVID-19 and physical activity

## Bibliometric analysis

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**Abstract**

**Background:** Containment measures implemented during the COVID-19 pandemic have led to drastic changes in daily life and effects on health behaviors such as decrease in physical activity (PA) levels. This study aims to present a general framework to researchers on COVID-19 and PA research in relation with changes in studies within years, current trend topics, gaps in the research field and possible future trends.

**Methods:** A total of 1819 articles indexed in the WoS core collection database were analyzed according to publication year, citation, country and institution collaborations, coword, co-citation networks, concept–topic trends and topic clusters using bibliometric analysis.

**Results:** The most productive country was the USA(n = 335), and the most productive institution was University of London in UK (n = 38). The most cited publication was the study by Ammar et al, (2020) (n = 188). In 2020, the most popular topics were PA and health meanwhile in 2021 behavior, lifestyle, social media and in 2022 habits, long COVID, sleep quality topics were in the foreground. Studies in 2023 focus on how COVID-19 affects PA habits and the associations between COVID-19-based anxiety and sleep patterns. These studies focused especially on effects of sport participation on life quality, diet, depression, mental health on young athletes, children, adolescent persons, older adult groups.

**Conclusions:** An important gap in the study area is research on effect of changing lifestyle due to pandemic on individuals and the society during the Post COVID-19 period. If benefits of PA will not be limited to only physical benefits and psychological emotional, cognitive and social benefits are also taken into consideration, it is important that researchers conduct long-term and widescale observations.

**Abbreviations:** COVID-19 = Coronavirus Disease 2019, LLR = Log-Likelihood Ratio, MeSH = Medical Subject Heading, PA = Physical Activity, SARS-CoV-2 = Severe Acute Respiratory Syndrome Coronavirus 2, TF-IDF = Frequency-Inverse Document Frequency, UK = The United Kingdom, USA = The United States of America, WHO = World Health Organization, WoS = Web of Science.

**Keywords:** bibliometrics, coronavirus, COVID-19, physical activity, SARS-CoV-2

## 1. Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) first emerged in Wuhan, China, in December 2019 and the resulting disease was named, coronavirus disease 2019 (COVID-19) by the World Health Organization (WHO).[1] After the rapid spread of the virus and the increase in the number of cases worldwide, the WHO declared this situation a pandemic on March 11, 2020,[2] and it was the fifth pandemic since the Spanish Flu pandemic back in 1918.[3] The COVID-19 pandemic has caused direct and indirect effects in many domains including health, social, economic and psychological conditions.[4–7] COVID-19 pandemic is a field of study where interdisciplinary analyses should be carried out with its cross-sectional aspect.[8] As the transmission of COVID-19 among individuals was by direct contact or droplets,[9] measures such as stay-at-home, lockdown, quarantines, social restrictions, and social distancing were implemented to limit the spread of the virus and minimize adverse effects. Indeed, changes in daily life have impacted physical activity (PA) levels negatively across all ages[10–12] and in different groups such as adolescents, university students, individuals with chronic conditions, paralympic athletes, and those with disabilities.[13–20]

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*The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.*

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In the systematic review and meta-analysis carried out by Wunsch et al 2022, that investigated changes in PA patterns resulting from the COVID-19 pandemic until October 6, 2021, 57 studies from 14 countries involving participants between the ages of 4 and 93 were included. According to this systematic review and meta-analysis, PA decreased substantially in all age groups, regardless of gender and in most countries during the COVID-19 pandemic.[2]

A decrease in PA, lower energy expenditures, and an increase in sedentary life may worsen chronic physical and mental health conditions and increase the risk related to these chronic conditions.[21] PA is one of the most basic requirements to improve health and health-related quality of life.[22] It is widely reported that insufficient PA causes multiple health conditions.[2,23–27]

Low or insufficient levels of PA over the long term may lead to losses of muscle strength and mass, decreases in endurance capacity, tendon ruptures, and reduced joint tribology.[26] Regular PA can support the immune function to heal viral respiratory tract infections, as caused by coronavirus, by promoting the release of stress hormones (catecholamines and glucocorticoids) responsible for reducing excessive local inflammation in the respiratory tract and inducing the secretion of anti-inflammatory cytokines such as IL-4 and IL-10.[28] Moreover, it has the ability to delay the onset of immunosenescence, which is defined as immune dysregulation caused by aging.[29]

The scientific research on COVID-19 and PA has increased exponentially with the emergence of the pandemic due to the protective and curative effects of PA on health. These studies have been summarized through reviews.[2,30–32]

Especially due to their contributions to facilitating the follow-up of the accumulated evidence in the area and reducing prejudgments, systematic reviews are preferred by researchers and make significant contributions to the relevant area.[33,34]

Bibliometric studies conducted during COVID-19 period exhibited that the most productive countries were USA, UK, Italy,[35–40] institutions were Temple, Anglia Ruskin universities, Federal University of Santa Maria,[36] and Harvard Medical School.[40] Another finding presented by these studies showed that the most cited authors were Ammar (2020); Stanton (2020); Chen (2020); and Di Renzo' (2020).[35,36,39,40] The studies conducted were focusing more on topics such as gender, youth, sedentary behavior in children, mental health, the credibility of PA assessment tools'; sedentary behavior, physical inactivity, medical conditions, health behaviors, PA/sedentary behavior-related policies, programs, recommendations, and guidelines; mental health, lifestyle, quality of life.[35,38,39] Some of the abovementioned bibliometric studies on COVID-19 and PA handled a period of 1 year until January 2021,[35,37] some included a period of 2 years until February 2022[38,40] and the other 2 examined the period until the second quarter of 2022.[36,39] The existing studies in the literature have compiled studies that examined the process in which COVID-19 was recognized as a pandemic and the acute effects of sedentary life on the individual and society in this process, considering the date they were conducted. Whereas pandemics leave their traces on the society and cause a change in the social life,[41] they can create a new "normality" by shaping the communication style and living quarters of individuals.[42] This new normality and the changes in work life, education, access to knowledge, and sport services deserve to be studied thoroughly. Although in recent years, the pandemic showed a downward trend due to the increase in immunization of the population by getting vaccinations and infection, decrease in the rate of mortality and decrease in the demand to health systems[43] researchers still show a considerable attention to the topic of COVID-19 and PA. One of the important gaps in the study area is to find out to which direction the studies on COVID-19 and PA evolved under the new normality situation.

Therefore, this study aimed to investigate topic trends, changes in the most contributing countries, institutes and authors according to years and their collaborations. Besides these, the current hotspot topics, research gaps in the study field were detected and considerable suggestions were presented for the future researchers in this field. In order to achieve the objective of the study, in addition to previous studies, the existing literature has been addressed more comprehensively and the unit of analysis has been widened and the data were examined both quantitatively and qualitatively.

## 2. Methods

### 2.1. Analysis tool and procedure

The bibliometric study is a comprehensive technique that uses mathematical and statistical analysis by visualizing the data of all written publications such as books, papers, and articles obtained to reveal the quantitative relationship in different areas of study and determine the change and distribution in the literature.[44–47] Ethical issues were taken into consideration by the authors of the study.

### 2.2. Database

In this study, we preferred to use Web of Science (WoS) as the database. WoS has become a significant database for studies by carefully compiling the world's most important literature index[48–50] and the WoS database is considered a secure data source used by many bibliometric studies.[51,52] Moreover, another reason why we preferred the WoS database is that the CiteSpace analysis software works with the WoS database in a secure and integrated way[50] and is a database that can provide researchers with complete indexes and references.[53]

### 2.3. Search strategy

It is important to state the research criteria in detail to be able to repeat a scientific study with the same method and verify the results obtained. In this study, we primarily determined our criteria in detail and did our search in quotes in the search box in the WoS Core Collection database and in titles to eliminate the ineligible studies that could be obtained. The screening was performed by 2 independent researchers, and information such as the publication titles of the studies, publication years, and the names of the authors were checked by the researchers to provide the validity of the data obtained. Furthermore, each study was evaluated in terms of compliance with the scope. Considering the large amount of data used in bibliometric studies, the control of the data obtained is important since they affect the overall results of the study.

### 2.4. Inclusion step

The screening was limited to studies conducted between 2020 and April 4, 2023. The keywords searched were determined using the MeSH (Medical Subject Heading) database.[54] The screening was carried out, by writing "TI=('physical activity' and 'coronavirus' (Title) or 'physical activity' and 'sars-cov-2' (Title) or 'physical activity' and 'COVID-19' (Title) or 'physical activity' and 'SARS Coronavirus 2 Infection' (Title) or 'physical activity' and 'SARS-CoV-2 Infection' (Title) or 'physical activity' and 'Severe Acute Respiratory Syndrome Coronavirus 2 Infection' (Title) or 'physical activity' and '2019 Novel Coronavirus' (Title) or 'physical activity' and '2019-nCoV' (Title) or 'exercise' and 'coronavirus' (Title) or 'exercise' and 'sars-cov-2' (Title) or 'exercise' and 'COVID-19' (Title) or 'exercise' and 'SARS Coronavirus 2 Infection' (Title) or 'exercise' and 'SARS-CoV-2 Infection' (Title) or 'exercise' and 'Severe Acute Respiratory Syndrome Coronavirus 2 Infection' (Title) or 'exercise' and '2019 Novel Coronavirus' (Title) or 'exercise' and '2019-nCoV' (Title) or 'sport' and 'coronavirus' (Title) or 'sport' and 'sars-cov-2' (Title) or 'sport' and 'COVID-19' (Title) or 'sport' and 'SARS Coronavirus 2 Infection' (Title) or 'sport' and 'SARS-CoV-2 Infection' (Title) or 'sport' and

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'Severe Acute Respiratory Syndrome Coronavirus 2 Infection' (Title) or 'sport' and '2019 Novel Coronavirus' (Title) or 'sport' and '2019-nCoV' (Title) and Article and Review Article (Document Types) and English (Languages)". The inclusion and exclusion criteria were presented in the PRISMA flow chart (Fig. 1).[55]

### 2.5. Exclusion step

The exclusion criteria of our study were specified as follows.

(1) Scopus, Pumbed, and so on were not included in the analysis.
(2) 683 studies in gray literature were not included in the study.
(3) Four duplicated studies were found and excluded from the study.
(4) Non-English studies weren't included in the analysis.

### 2.6. Data analysis and visualization

In this study, CiteSpace 6.2.R2 was utilized as a visualization software. As a result of the analyses, we obtained modularity,[56–58] weighted mean silhouette values,[58,59] network density, frequency-inverse document frequency (TF-IDF), and a log-likelihood ratio (LLR) algorithm.

### 2.7. Research ethics

Ethical approval was not required because secondary data were used in this study. But all ethical issues (including informed, plagiarism, data fabrication and/or falsification, misconduct, redundancy, double publication, and/or submission) were taken into consideration by the authors.

## 3. Results

It was found that studies on COVID-19 and PA began in 2020 and in 2021, it has increased nearly 3 times. It was seen that the studies on COVID-19 and PA maintained their popularity in 2022 (Table 1).

### 3.1. Country and institution collaboration

The findings of country and institution collaboration provide considerable information on institutions and countries of the researchers. The ranking of the countries with more than 100

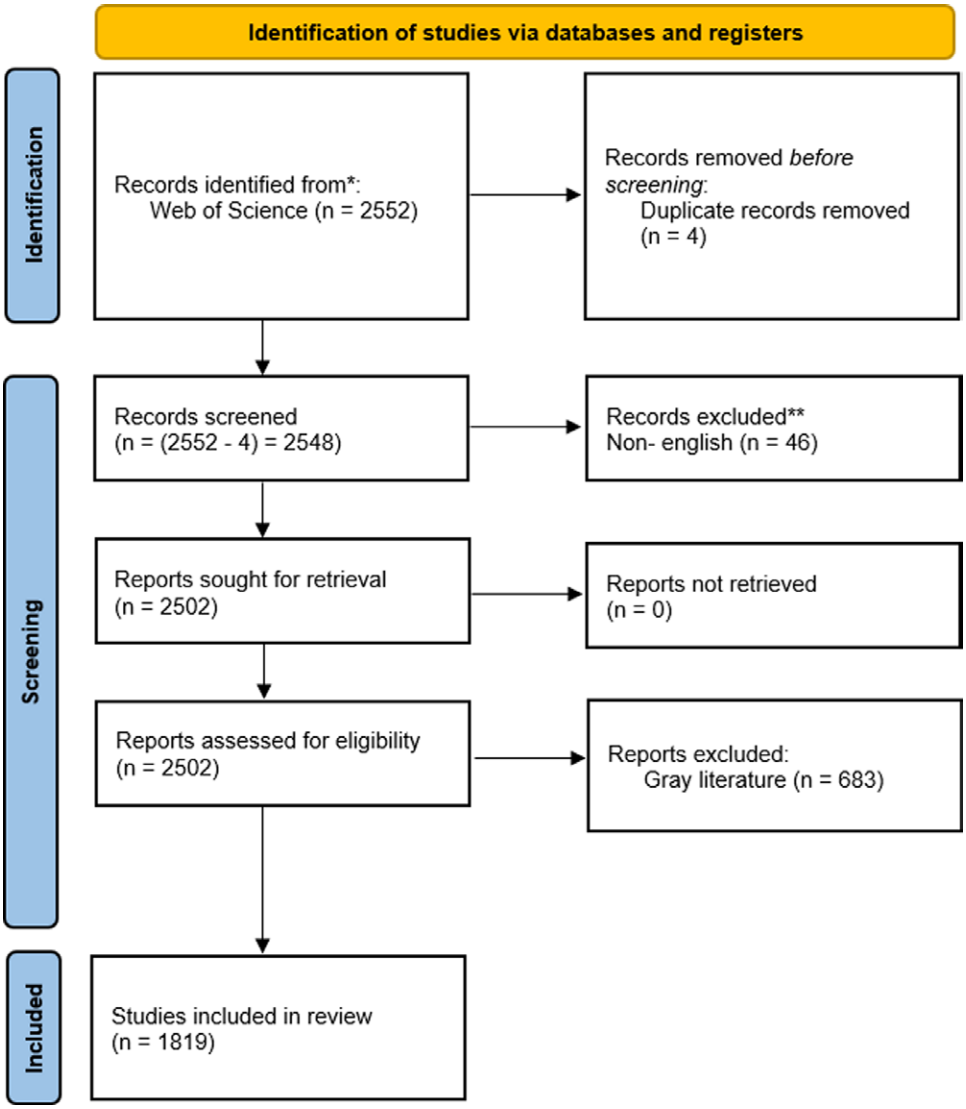


**Figure 1.** PRISMA flow chart.

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publications and institutes with more than 18 publications can be examined in Table 2. Figure 2 provides information about the major countries, institutes, and collaborations between them in the network.

### 3.2. Citation analysis

It was detected that 1819 studies on PA and COVID-19 were cited 26.686 times. Due to the 3 times increase in the number of studies compared to the previous year, the number of citations increased systematically as well. According to Table 3, there are 10 studies with the number of citations over 400. The topic clustering of the most cited sources is presented in Figure 3.

Table 4 demonstrates the topic clustering of the references cited by the studies on PA and COVID-19. In order to specify the clustering in the network and exhibit the homogeneity of the clusters, LLR method was used. According to LLR method the network was divided into 8 clusters and clues related with the trend topics were given.

**Table 1**

**Distribution of articles according to years.**

| Year | Frequency (n) | Percent (%) |
|---|---|---|
| 2020 | 264 | 14.51 |
| 2021 | 736 | 40.46 |
| 2022 | 725 | 39.8 |
| 2023 (First 3 mo) | 94 | 5.16 |
| Total | 1819 | 100 |

### 3.3. Coword network analysis

Tables 5 presents the most frequently included concepts in the abstract and keywords section of the studies. Coword analysis offers clues about the hotspot topics in the field of study, the change of these topics over the years, and current topic trends (Fig. 4).

## 4. Discussion

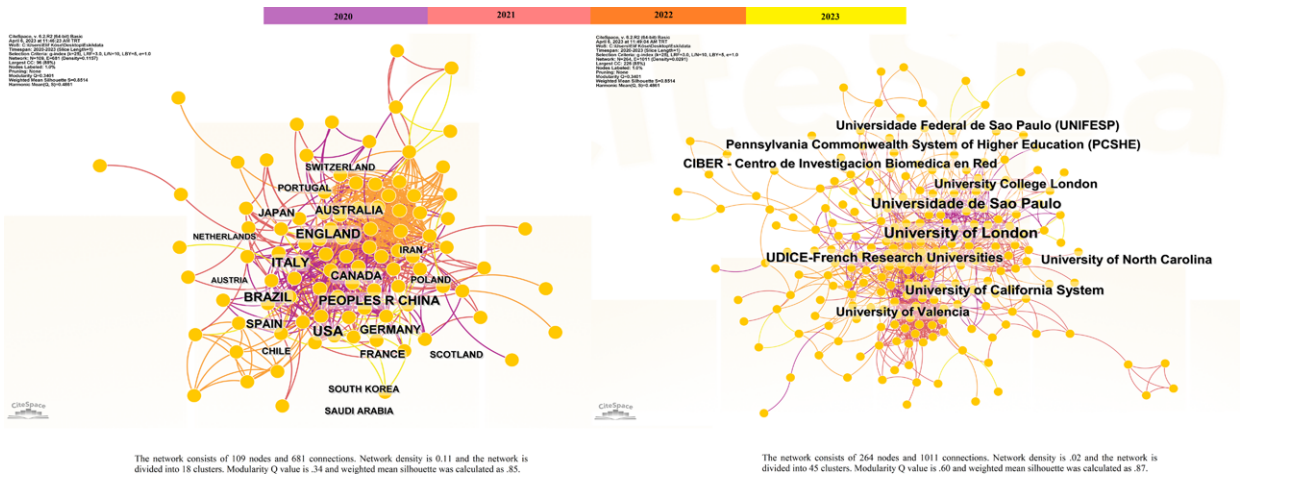
According to the analysis results, studies on COVID-19 and PA were first published in 2020, and the studies conducted in 2021 increased approximately 3 times compared to the previous year. It is detected that the interest in the subject continued during 2022.

According to the analysis results, the most productive country in the research area was the USA with 335 publications. This is not considered a surprising result since the USA has the highest number of scientific research institutes and large amounts of scientific research funds in the world,[60] and authors from the USA are seen to rank first in various scientific studies.[38,40] Following the USA, the most contributing countries to the field were found out to be UK and Italy. The findings show that the most publishing countries were from Europe and America continents. There may be 2 possible explanations to these findings: (1) These countries are among the countries which were touched heavily by COVID-19 pandemic[61]; (2) They are countries with high income levels. The results of the study show accordance with other studies.[36–39] In spite of the fact that China was the country where the pandemic first emerged with high number of cases and deaths and ranked first in the number of publications in bibliometric analyses in the WoS, PubMed, and Scopus databases,[62] China was only at the fourth place in the list of

**Table 2**

**Countries and institutions that published on "physical activity and COVID-19."**

| Countries | Frequency (n) | Percent (%) | University | Frequency (n) | Percent (%) |
|---|---|---|---|---|---|
| USA | 335 | 18.41 | University of London | 38 | 2.08 |
| UK | 181 | 9.95 | Sao Paulo | 29 | 1.59 |
| Italy | 160 | 8.79 | University of California | 22 | 1.20 |
| China | 157 | 8.63 | UDICE-French Research | 21 | 1.15 |
| Brasil | 150 | 8.24 | CIBER-Centro de Inv. Bio | 20 | 1.09 |
| Spain | 141 | 7.75 | University of College London | 20 | 1.09 |
| Canada | 109 | 5.99 | University of North Carolina | 19 | 1.04 |
| Germany | 100 | 5.49 | UNIFESP-Sao Paulo | 18 | 0.98 |
| Australia | 100 | 5.49 | University of Valencia | 18 | 0.98 |




The network consists of 109 nodes and 681 connections. Network density is 0.11 and the network is divided into 18 clusters. Modularity Q value is .34 and weighted mean silhouette was calculated as .85.

The network consists of 264 nodes and 1011 connections. Network density is .02 and the network is divided into 45 clusters. Modularity Q value is .60 and weighted mean silhouette was calculated as .87.

**Figure 2.** Country and institution collaborations.

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**Table 3**

**Top 10 most cited sources.**

| Authors | Year | Article title | Frequency (n) | Source title | Cluster # |
|---|---|---|---|---|---|
| Ammar et al[56] | 2020 | Effects of COVID-19 Home Confinement on Eating Behaviour and Physical Activity: Results of the ECLB-COVID-19 International Online Survey. | 188 | Nutrients | 0 |
| Chen et al[18] | 2020 | Coronavirus disease (COVID-19): The need to maintain regular physical activity while taking precautions. | 162 | J Sport Health Sci | 3 |
| Brooks et al[57] | 2020 | The psychological impact of quarantine and how to reduce it: rapid review of the evidence. | 138 | Lancet | 0 |
| Lesser et al[58] | 2020 | The impact of COVID-19 on physical activity behavior and well-being of Canadians | 138 | INT J ENV RES PUB HE. | 0 |
| Stockwell et al[29] | 2021 | Changes in physical activity and sedentary behaviors from before to during the COVID-19 pandemic lockdown: a systematic review. | 123 | BMJ open sport & exercise medicine. | 0 |
| Maugeri et al[23] | 2020 | The impact of physical activity on psychological health during Covid-19 pandemic in Italy. | 115 | Heliyon | 0 |
| Tison et al[59] | 2020 | Worldwide effect of COVID-19 on physical activity: a descriptive study. | 109 | Annals of internal medicine | 0 |
| Meyer et al[60] | 2020 | Changes in physical activity and sedentary behavior in response to COVID-19 and their associations with mental health in 3052 US adults. | 98 | Int. J. Environ. Res. Public Health | 0 |
| Hall et al[61] | 2021 | A tale of 2 pandemics: How will COVID-19 and global trends in physical inactivity and sedentary behavior affect 1 another? | 98 | Progress in cardiovascular diseases | 3 |
| Stanton et al[62] | 2020 | Depression, Anxiety and stress during COVID-19: Associations with changes in physical activity, sleep, tobacco and alcohol use in Australian adults. | 93 | Int. J. Environ. Res. Public Health | 0 |

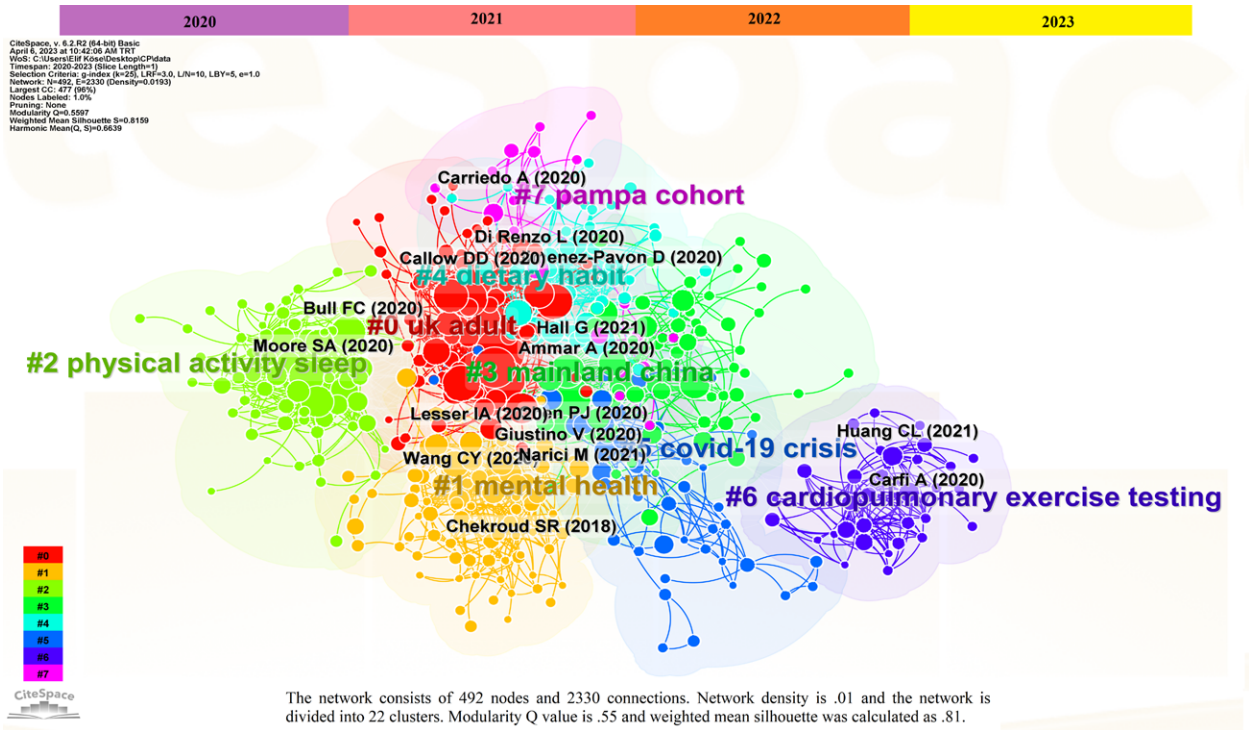


**Figure 3.** Network structure of the publications with common citation.

the top 9 most productive countries. One of the reasons for this result might be the fact that most of the researchers were diverted toward areas such as the prevention of coronavirus, drug therapy, vaccines, and critical care. The other reason might be due to the fact that publications in Chinese were not included in this analysis. During the pandemic, many researchers might have published quickly in their native languages and journals in their own countries. In previous research the top contributing institutions had been ranked as: Sbarro Institute for Cancer Research and Molecular Medicine (USA), Temple University (USA), Anglia Ruskin University (UK)[36]; Federal University of Minas Gerais (Brazil) University of Sao Paulo (Brazil), Anglia Ruskin University[35]; Anglia Ruskin University; University of Palermo (Italy), Ulster University (UK).[37] As for this study; the leading institutions contributing to the area were the University of London in UK (n = 38) and Sao Paolo University in Brazil (n = 29). University of California in USA (n = 22), UDICE-French Research in France (n = 21), and CIBER-Centro de Inv. Bio University in Spain (n = 20) were detected to contribute respectively. Even the names of the most contributing institutions may change, the most productive countries are still the USA, UK and Brasil.

Another notable finding of the analysis is the list of the most cited studies within 1819 studies. The studies of Ammar et al (2020), Chen et al (2020), and Brooks et al (2020) were still observed among the most cited studies in the area.[35–37,39,40]

The study titled "Effects of COVID-19 Home Confinement on Eating Behavior and Physical Activity: Results of the

**Table 4**

**Topic clusters according to co-citation network analysis.**

| Cluster | Size | Mean Silhouette | Year | Label (MI) | Label (LLR) |
|---|---|---|---|---|---|
| 0 | 107 | 0.739 | 2020 | Social-distancing rule (2.21); special focus (2.21) | UK adult (350.91, 1.0E-4); subjective well-being (339.3, 1.0E-4); physiotherapy student (330.6, 1.0E-4); internet addiction (330.6, 1.0E-4); national longitudinal survey (278.35, 1.0E-4) |
| 1 | 88 | 0.742 | 2019 | Social-distancing rule (1.41); special focus (1.41) | Mental health (830.84, 1.0E-4); chinese college student (440.96, 1.0E-4); Australian adult (379.71, 1.0E-4); covid-19 epidemic (373.48, 1.0E-4); depression symptom (358.89, 1.0E-4) |
| 2 | 69 | 0.893 | 2019 | Social-distancing rule (1.18); special focus (1.18) | Physical activity sleep (699.85, 1.0E-4); parents perspective (607.17, 1.0E-4); ontario children (587.02, 1.0E-4); sedentary behavior (458.6, 1.0E-4); longitudinal change (434.02, 1.0E-4) |
| 3 | 68 | 0.842 | 2019 | Social-distancing rule (2.14); special focus (2.14) | Mental health (667.92, 1.0E-4); mainland china (369.83, 1.0E-4); states adult (360, 1.0E-4); college student (269.39, 1.0E-4); hungarian online survey (254.15, 1.0E-4) |
| 4 | 51 | 0.789 | 2020 | Social-distancing rule (1.17); special focus (1.17) | Dietary habit (529.08, 1.0E-4); body weight (387.25, 1.0E-4); eating habit (329.25, 1.0E-4); weight status (326.22, 1.0E-4); weight physical activity (241.9, 1.0E-4) |
| 5 | 41 | 0.874 | 2020 | Social-distancing rule (2.21); special focus (2.21) | Covid-19 crisis (515.02, 1.0E-4); physical activity nutrition (347.82, 1.0E-4); amateur football (340.89, 1.0E-4); support staff (321.27, 1.0E-4); summer extension (321.27, 1.0E-4) |
| 6 | 32 | 0.974 | 2020 | Physical activity (0.14); covid-19 pandemic (0.09) | Cardiopulmonary exercise testing (923.17, 1.0E-4); cardiopulmonary exercise capacity testing (464.19, 1.0E-4); cardiopulmonary exercise capacity (381.99, 1.0E-4); physical activity (347.4, 1.0E-4); covid-19 pandemic (332.05, 1.0E-4) |
| 7 | 2 | 0.889 | 2020 | Social-distancing rule (0.13); special focus (0.13) | Pampa cohort (278.3, 1.0E-4); subjective memory decline (278.3, 1.0E-4); covid-19 pandemic era (226.31, 1.0E-4); 3-wave cross-lagged study (226.31, 1.0E-4); specific type (218.95, 1.0E-4) |

**Table 5**

**Statistics on most-repeated words/ Coword statistics according to years.**

| Number of citations | Words | Year |
|---|---|---|
| 767 | Physical activity & | 2020 |
| 281 | Exercise | 2020 |
| 253 | Health | 2020 |
| 207 | Mental health | 2020 |
| 146 | Sedentary behavior | 2020 |
| 138 | Depression | 2020 |
| 136 | Adults | 2020 |
| 129 | Impact | 2020 |
| 120 | Anxiety | 2020 |
| 105 | Risk | 2020 |
| 100 | Quality of life | 2020 |
| 88 | Reliability | 2020 |
| 87 | Validity | 2020 |
| 84 | Children | 2020 |

ECLB-COVID-19 International Online Survey" (n = 585) by Ammar et al (2020) was cited 896 times.[63] In this study, which had been published in the early period of the pandemic, it was stated that the measures taken to prevent the spread and transmission of the virus, such as travel restrictions/prohibitions, closure of schools, and lockdowns, would reduce physical activities and increase sedentary life of people, which might affect health adversely. It was stressed that exercise should be done at home for health, and suggestions were given about exercises that could be done at home. Another study is the study titled "The psychological impact of quarantine and how to reduce it: rapid review of the evidence" (n = 138) by Brooks et al.[64] It is a review study investigating the psychological effects of quarantine, which used 3 electronic databases and was published in Lancet in the early period of the pandemic (on February 26, 2020). The publication of the study in a prestigious journal such as Lancet with very high IFs in Q1 in (2020, IFs 79.323), JCR Medicine, General & Internal category in SCIE edition may explain the fact that it is the third most cited study. In bibliometric analysis, it is usually stated that IFs are proportional to citation frequency.[1] Furthermore, the fact that the study is a review and gives suggestions to politicians and health officials about what needs to be done in the quarantine may have influenced the number of citations.

Measures such as social isolation, social distancing, lockdown, and quarantines implemented in different ways in different countries during the pandemic changed the daily life habits of people and led to an increase in sedentary life in all age groups in most countries.[2] Therefore, first year studies conducted during the beginning period of pandemic considered the biopsychosocial impacts of COVID-19 on individuals and focused on physical (body mass index, nutrition, inactivity, etc) and psychologic (anxiety, depression, life quality, etc) effects and the precautions and Guidelines that will decrease these effects. Regular PA has positive effects on all body systems, such as musculoskeletal, respiratory, hormonal, immunological systems,[27] and psychological conditions such as an increase in sleep quality, life quality, and self-confidence and a decrease in anxiety and depression.[65] Considering the importance of PA, it is likely that the interest of researchers in this area will grow and the number of publications will increase in parallel. The other studies which became popular in 2020 were reliability and validity studies of new measurement tools devoted to PA measurement during COVID-19 pandemic.[39] The growing emphasis given on PA during COVID-19 pandemic might have increased the importance of validity and reliability of PA measurement.

In 2021 meanwhile researchers continued to inquire about the impact of PA on physical and mental health, they published guidelines and conducted research on changing lifestyle and social media usage. Bibliometric studies analyzing 2020–2021 data on COVID-19 and PA showed accordance with our findings and showed that the preliminary studies focused on PA, mental activity and lifestyle.[35,36,38–40] Considering that public health recommendations such as the closure of schools and gyms, social isolation, and lockdown within the scope of COVID-19 restrictions and measures taken by governments had changed people's daily life routines and affected health

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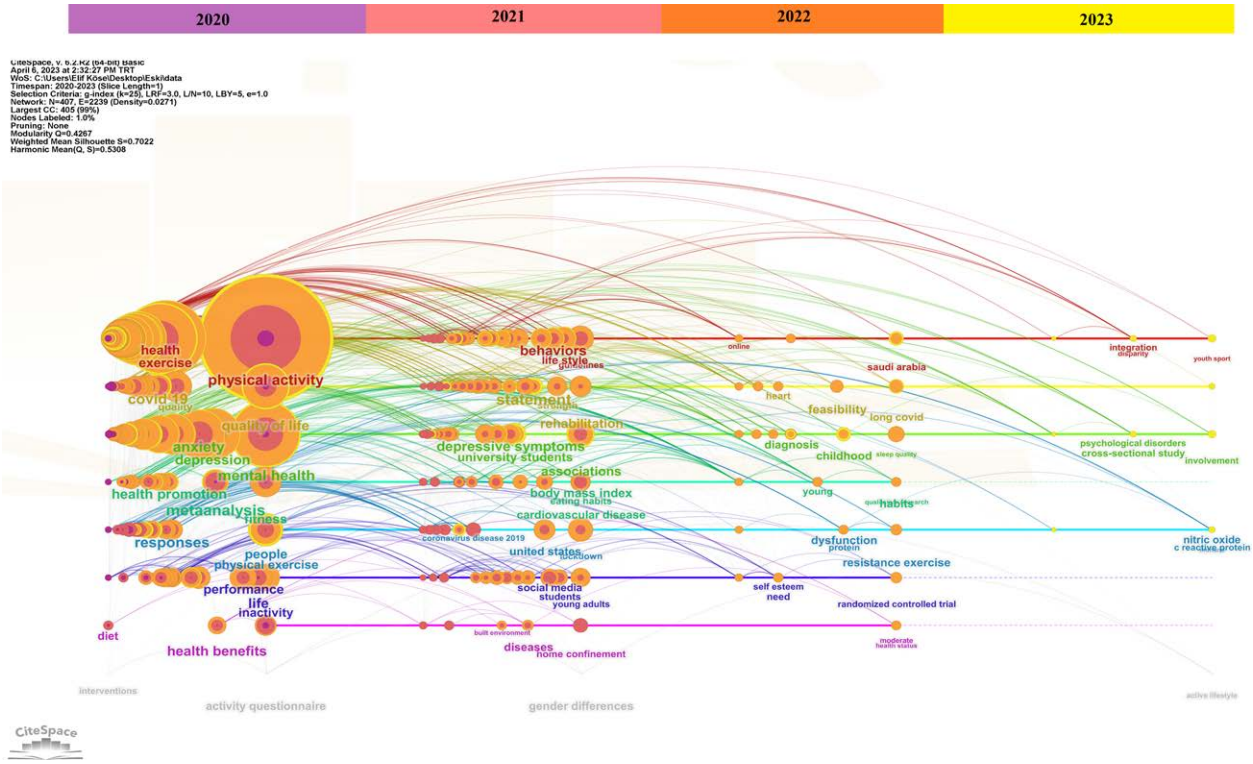


**Figure 4.** Word cloud of most-repeated words.

behaviors such as eating behaviors and PA, these concepts are likely to come to the forefront. These restrictions have increased sedentary lifestyles[2] and caused changes in eating attitudes and behaviors such as the type and amount of food consumed, the number of meals, and eating between meals. Moreover, problems such as concerns, anxiety, and boredom during the quarantine and problems related to food production and supply might have affected the eating attitudes and behaviors of people.[41,63] Apart from the previous studies, this study reveals that PA and social media usage during COVID-19 period attracted the interest of researchers. In order to reduce the disadvantages experienced due to the restrictions brought by pandemic conditions to a minimum, trainers, and fitness centers offered alternative suggestions to their customers. One of the main suggestions was the usage of social media. Although the importance of social media was mentioned previously by Abeza et al (2015),[66] its intensive use in the context of sport increased rapidly during pandemic period.[67]

The most frequently studied topics were habits, sleep quality, childhood Long COVID-19, and randomized controlled trials during 2022. COVID-19 pandemic caused changes in habits related with hygiene, nutrition, exercise, and so on.[68] For instance, studies examining children[69] and adults[70] reported that there was a recovery in PA levels of children and adults after the lockdown was released; however, this level could not reach the same level before the pandemic. Other topics that attracted the interest of researchers were the way COVID-19 affected PA habits[71,72] and the relationship between COVID-19 based anxiety and sleeping pattern[73,74] and the sample consisted of individuals in childhood period. These studies inquired about how COVID-19 affected PA levels of children, if the PA level of children changed due to the release of lockdown and PA habits and needs of children.[75,76] Recent systematic analyses and review studies have also revealed that the COVID-19 pandemic has a significant impact on the level of PA of healthy adults on sleep behavior. As the duration of PA decreases, sleep quality decreases and sleep duration increases.[77] Although the acute phase of the pandemic is finished, new difficulties came out related with COVID-19. Post COVID-19 period continues developing especially physical and respiratory symptoms months after the beginning of the disease.[78] At the beginning of the pandemic, COVID-19 was considered to be a short-term disease. By using the data at the beginning period of pandemic WHO declared that the recovery period was 2 weeks for individuals with mild symptoms and 3–6 for individuals with severe symptoms.[79] Later on, Long COVID-19 Syndrome was detected which caused that the COVID-19 symptoms such as fatigue, shortness of breath, chest pain, tachycardia, insomnia lasted more than 12 weeks.[80]

The fact that PA is a therapeutic method of coping with the results of COVID-19 infection by improving the immune system, researchers developed interest in PA and they presented PA as a suggestion to overcome the symptoms. In addition to that they predicted an increase in the number of randomized controlled trials for future studies by considering the past studies inquiring the effect of PA on the general population.[39] In accordance with this prediction, it was detected that randomized controlled trials increased during the last period.

Towards the end of 2022 and at the first quarter of 2023, there was a trend towards the topics such as youth sport, involvement, randomized and cross-sectional studies. These studies focused especially on effects of sport participation on life quality, diet, depression, mental health on young athletes, children, adolescent persons, older adult groups. One of the systematic studies on adults and the elderly found that supervised exercise had an effect on anxiety and depression levels in individuals with chronic diseases.[81] Another randomized study looking at the effects of a telehealth exercise program on pain, sleep and depression in women with fibromyalgia pain during the pandemic found that exercise was effective in both the control and experimental groups, but the experimental group had higher scores.[82] In an experimental study in which subjects were subjected to 12 weeks of resistance and aerobic exercise, it was reported that the depression levels of the subjects decreased significantly compared to the baseline.[83] A 14-day therapeutic exercise based on strength and breathing exercises is reported

to be effective in improving people's physical and respiratory functions.[78]

### 4.1. Research gap and future directions

It is crucial to conduct studies examining the changing lifestyle caused by the pandemic, unhealthy behaviors such as smoking, alcohol consumption and malnutrition during the Post COVID-19 period[68] for the fact that these unhealthy behaviors are related with serious diseases which can have long-term physical health effects.[84] Rawat et al (2021) stated that studies on COVID-19 pandemic focused mainly on physical and mental health, and other problems resulting from lifestyle behaviors were neglected.[85] However, the deterioration in lives of individuals and the society due to economic problems, poverty, increase in food insecurity, difficulties in accessing education and PA, getting isolated should be taken in consideration. If benefits of PA will not be limited to only physical and psychological benefits and emotional, cognitive and social benefits are also taken into consideration, the benefits of PA will be a topic at the forefront.

The restrictions during COVID-19 pandemic, might have led to perceptions such as being separated from others, disappointment and boredom.[86] Perception of boredom is an important theme in leisure literature and predominantly was related with loneliness,[87] psychologic well-being, emotional distress,[88] addiction[89] and aggression.[90] Yet, problems individuals, families and the whole society may face due to the behavioral problems which boredom may affect such as developing addiction or aggression, deserve more extensive studies.

When the samples of the studies mentioned in this research are considered many studies were observed on young individuals, women, children, disabled individuals and elderly individuals. According to Mehmood et al (2022), air pollution and COVID-19 affect disadvantaged groups more. Therefore, in these groups where the need is more urgent, measures should be taken quickly.[91] When the literature is examined, studies on disadvantaged groups such as LGBTQ + individuals or prisoners are relatively less. The effect of pandemic on these groups deserves more comprehensive research. Because LGBTQ + individuals might have problems in accessing health services due to being considered marginal and this might have got worse during the COVID-19 pandemic. The role of PA in coping with those problems during post COVID-19 period can be handled by researchers.

In the future when the number of studies on COVID-19 and PA increases, meta-analysis studies merging the results of these studies are expected to attract more attention from researchers. During the pandemic period, social media and technological opportunities (such as virtual reality) were used actively in the context of exercise. These opportunities may become "new alternatives/normality" for the post COVID-19 period. The advantages and disadvantages of these opportunities during post COVID-19 period are among the topics which are worth considering.

### 4.2. Limitations

Our study is the most wide-ranging study concerning the "publication years" among the bibliometric studies on COVID-19 and PA in the literature. However, only 1819 studies were included in this research which were indexed in WoS database during 2020 January to 2023 April 4. Meanwhile studies indexed in PubMed, Scopus or other databases, gray literature and publications in nonindexed journals were not included. In addition to that, publications only in English language were analyzed so the results of the research which are not in English language were not taken into consideration.

## 5. Conclusions

This study helps researchers conducting research in this area to gain a macro-perspective on the structure and evolution of the research area and trends in academic activity. The findings may provide an objective reference for researchers, journal editors, and reviewers. Furthermore, studies on this subject may create a road map regarding new pandemics and PA. Even when the pandemic ends, it is assumed that changes in PA and eating behaviors experienced during this period as well as psychological and behavioral effects will not disappear immediately. How the pandemic will affect children, older adults, young people, LGBTQ + individuals and disabled individuals and overall society, in other words, all humanity in the future is an important matter of curiosity. What kind of consequences may arise during the following processes due to the problems resulting from an isolated lifestyle and immobility throughout the pandemic period? is another question. Hence it is important to state that "COVID-19 and PA" is a topic requiring long-term and large-scale monitoring by researchers.

## Author contributions

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**Writing – review & editing:** Evren-Tercan Kaas, Ali Serdar Yücel, Süleyman Derman.

## References

[1] Zhai F, Zhai Y, Cong C, et al. Research progress of coronavirus based on bibliometric analysis. Int J Environ Res Public Health. 2020;17:3766.
[2] Wunsch K, Kienberger K, Niessner C. Changes in physical activity patterns due to the COVID-19 pandemic: a systematic review and meta-analysis. Int J Environ Res Public Health. 2022;19:2250.
[3] Mehmood K, Bao Y, Petropoulos GP, et al. Investigating connections between COVID-19 pandemic, air pollution and community interventions for Pakistan employing geoinformation technologies. Chemosphere. 2021;272:129809.
[4] Madjid M, Safavi-Naeini P, Solomon SD, et al. Potential effects of coronaviruses on the cardiovascular system: a review. JAMA Cardiol. 2020;5:831–40.
[5] Vindegaard N, Benros ME. COVID-19 pandemic and mental health consequences: systematic review of the current evidence. Brain Behav Immun. 2020;89:531–42.
[6] Pokhrel S, Chhetri R. A literature review on impact of COVID-19 pandemic on teaching and learning. Higher Educ Future. 2021;8:133–41.
[7] Nicola M, Alsafi Z, Sohrabi C, et al. The socio-economic implications of the coronavirus pandemic (COVID-19): a review. Int J Surg. 2020;78:185–93.
[8] Mehmood K, Bao Y, Mushtaq S, et al. Perspectives from remote sensing to investigate the COVID-19 pandemic: a future-oriented approach. Front Public Health. 2022;10:938811.
[9] Mehmood K, Bao Y, Abrar MM, et al. Spatiotemporal variability of COVID-19 pandemic in relation to air pollution, climate and socioeconomic factors in Pakistan. Chemosphere. 2021;271:129584.

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[10] Martínez-de-Quel O, Suárez-Iglesias D, López-Flores M, et al. Physical activity, dietary habits and sleep quality before and during COVID-19 lockdown: a longitudinal study. Appetite. 2021;158:105019.

[11] Sasaki S, Sato A, Tanabe Y, et al. Associations between socioeconomic status, social participation, and physical activity in older people during the COVID-19 pandemic: a cross-sectional study in a northern Japanese city. Int J Environ Res Public Health. 2021;18:1477.

[12] Tulchin-Francis K, StevensWJr, Gu X, et al. The impact of the coronavirus disease 2019 pandemic on physical activity in US children. Sports Med Health Sci. 2021;10:323–32.

[13] Balci B, Aktar B, Buran S, et al. Impact of the COVID-19 pandemic on physical activity, anxiety, and depression in patients with Parkinson's disease. Int J Rehabil Res. 2021;44:173–6.

[14] Bertrand L, Shaw KA, Ko J, et al. The impact of the coronavirus disease 2019 (COVID-19) pandemic on university students' dietary intake, physical activity, and sedentary behaviour. Appl Physiol Nutr Metab. 2021;46:265–72.

[15] Elnaggar RK, Alqahtani BA, Mahmoud WS, et al. Physical activity in adolescents during the social distancing policies of the COVID-19 pandemic. Asia Pac J Public Health. 2020;32:491–4.

[16] Fettes L, Bayly J, de Bruin LM, et al. Relationships between prolonged physical and social isolation during the COVID-19 pandemic, reduced physical activity and disability in activities of daily living among people with advanced respiratory disease. Chron Respir Dis. 2021;18:14799731211035822.

[17] Moore SA, Sharma R, Martin Ginis KA, et al. Adverse effects of the COVID-19 pandemic on movement and play behaviours of children and youth living with disabilities: findings from the National Physical Activity Measurement (NPAM) study. Int J Environ Res Public Health. 2021;18:12950.

[18] Ruiz-Roso MB, Knott-Torcal C, Matilla-Escalante DC, et al. COVID-19 lockdown and changes of the dietary pattern and physical activity habits in a cohort of patients with type 2 diabetes mellitus. Nutrients. 2020;12:2327.

[19] Shaw KA, Bertrand L, Deprez D, et al. The impact of the COVID-19 pandemic on diet, fitness, and sedentary behaviour of elite para-athletes. Disabil Health J. 2021;14:101091.

[20] Shima T, Nakao H, Tai K, et al. The influences of changes in physical activity levels with easing restriction of access to the university campus on empathy and social supports in college students during the COVID-19 pandemic. Asia Pac J Public Health. 2022;34:406–10.

[21] Chen P, Mao L, Nassis GP, et al. Coronavirus disease (COVID-19): the need to maintain regular physical activity while taking precautions. J Sport Health Sci. 2020;9:103–4.

[22] Alzahrani H, Alshehri F, Alsufiany M, et al. Impact of the 2019 Coronavirus disease pandemic on health-related quality of life and psychological status: the role of physical activity. Int J Environ Res Public Health. 2021;18:3992.

[23] Booth FW, Roberts CK, Laye MJ. Lack of exercise is a major cause of chronic diseases. Compr Physiol. 2012;2:1143–211.

[24] Fuezeki E, Engeroff T, Banzer W. Health benefits of light-intensity physical activity: a systematic review of accelerometer data of the National Health and Nutrition Examination Survey (NHANES). Sports Med. 2017;47:1769–93.

[25] Liska D, Andreansky M. Rehabilitation and physical activity for COVID-19 patients in the post infection period. Rehabilitation (Stuttg). 2021;122:310–4.

[26] Maugeri G, Castrogiovanni P, Battaglia G, et al. The impact of physical activity on psychological health during COVID-19 pandemic in Italy. Heliyon. 2020;6:e04315.

[27] Posadzki P, Pieper D, Bajpai R, et al. Exercise/physical activity and health outcomes: an overview of Cochrane systematic reviews. BMC Public Health. 2020;20:1–12.

[28] Ravalli S, Musumeci G. Coronavirus outbreak in Italy: physiological benefits of home-based exercise during pandemic. J Funct Morphol Kinesiol. 2020;5:31.

[29] Nieman DC, Wentz LM. The compelling link between physical activity and the body's defense system. J Sport Health Sci. 2019;8:201–17.

[30] López-Valenciano A, Suárez-Iglesias D, Sanchez-Lastra MA, et al. Impact of COVID-19 pandemic on university students' physical activity levels: an early systematic review. Front Psychol. 2021;11.

[31] Rossi L, Behme N, Breuer C. Physical activity of children and adolescents during the COVID-19 pandemic—A scoping review. Int J Environ Res Public Health. 2021;18:11440.

[32] Stockwell S, Trott M, Tully M, et al. Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: a systematic review. BMJ Open Sport Exerc Med. 2021;7:e000960.

[33] Gopalakrishnan S, Ganeshkumar P. Systematic reviews and meta-analysis: understanding the best evidence in primary healthcare. J Family Med Prim Care. 2013;2:9–14.

[34] Harris JD, Quatman CE, Manring M, et al. How to write a systematic review. Am J Sports Med. 2014;42:2761–8.

[35] Ciuldim M, Verlengia R, Crisp AH. A bibliographic analysis of primary studies on physical activity and COVID-19 during 2020–2021. Epidemiologia. 2022;3:314–22.

[36] Sofyan D, Abdullah KH, Akinci AY, et al. Sports activities during the Covid 19 pandemic: a bibliometric analysis. J Metrics Stud Soc Sci. 2022;1:50–60.

[37] Tomanek M, Lis A. Physical activity in the context of the COVID-19 pandemic: Research profiling and mapping. Phys Educ Students. 2021;25:136–48.

[38] Wattanapisit A, Kotepui M, Wattanapisit S, et al. Bibliometric analysis of literature on physical activity and COVID-19. Int J Environ Res Public Health. 2022;19:7116.

[39] Zhang F, Zhang Y, Yu Y, et al. Bibliometric analysis of the top-50 cited articles on COVID-19 and physical activity. Front Public Health. 2022;10.

[40] Zhang Y, Chen M, Liu C, et al. A bibliometric analysis of COVID-19 and physical activity. Medicine (Baltimore). 2022;101:e30779.

[41] Mattioli AV, Ballerini Puviani M. Lifestyle at time of COVID-19: how could quarantine affect cardiovascular risk. Am J Lifestyle Med. 2020;14:240–2.

[42] Dwivedi YK, Hughes DL, Coombs C, et al. Impact of COVID-19 pandemic on information management research and practice: transforming education, work and life. Int J Inf Manage. 2020;55:102211.

[43] WHO (World Health Organization). Director-General's opening remarks at the media briefing – 5 May 2023. Available at: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing---5-may-2023. [access date Aug 3, 2023].

[44] Hou Q, Mao G, Zhao L, et al. Mapping the scientific research on life cycle assessment: a bibliometric analysis. Int J Life Cycle Assess. 2015;20:541–55.

[45] Mao G, Liu X, Du H, et al. Way forward for alternative energy research: a bibliometric analysis during 1994–2013. Renew Sustain Energy Rev. 2015;48:276–86.

[46] Zupic I, Čater T. Bibliometric methods in management and organization. Organ Res Methods. 2015;18:429–72.

[47] Zhang X, Chen H, Wang W, et al. What is the role of IT in innovation? A bibliometric analysis of research development in IT innovation. Behav Inf Technol. 2016;35:1130–43.

[48] Ball R, Tunger D. Science indicators revisited–Science Citation Index versus SCOPUS: a bibliometric comparison of both citation databases. Inf Serv Use. 2006;26:293–301.

[49] Van Leeuwen T. The application of bibliometric analyses in the evaluation of social science research. Who benefits from it, and why it is still feasible. Scientometrics. 2006;66:133–54.

[50] Chen C. How to use CiteSpace. Victoria. British Columbia, Canada: Leanpub. 2015.

[51] Benckendorff P. Themes and trends in Australian and New Zealand tourism research: a social network analysis of citations in two leading journals (1994–2007). J Hospitality Tourism Manage. 2009;16:1–15.

[52] Boyack KW, Klavans R. Co-citation analysis, bibliographic coupling, and direct citation: which citation approach represents the research front most accurately? J Am Soc Inf Sci Technol. 2010;61:2389–404.

[53] Su X, Li X, Kang Y. A bibliometric analysis of research on intangible cultural heritage using CiteSpace. Sage Open. 2019;9:215824401984011.

[54] Alghoson AM. editor Medical document classification based on MeSH. 2014 47th Hawaii International Conference on System Sciences; 2014: IEEE.

[55] Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses. PLoS Med. 2009;6:e1000097.

[56] Jiang Y, Ritchie BW, Benckendorff P. Bibliometric visualisation: an application in tourism crisis and disaster management research. Curr Issues Tourism. 2019;22:1925–57.

[57] Chen C, Ibekwe-SanJuan F, Hou J. The structure and dynamics of cocitation clusters: a multiple-perspective cocitation analysis. J Am Soc Inf Sci Technol. 2010;61:1386–409.

[58] Li X, Ma E, Qu H. Knowledge mapping of hospitality research– A visual analysis using CiteSpace. Int J Hosp Manag. 2017;60:77–93.

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[59] Simovici DA. Chapter 6: data mining algorithms I: clustering. In: Math ANB, Stojmenović I, ed. Handbook of Applied Algorithms: Solving Scientific, Engineering and Practical Problems. 1th ed. John Wiley & Sons, Inc; 2007:177–217.

[60] Köse E, Seyman D, Yıldırım FS, et al. Bibliometric analysis of HIV and exercise literature based on scientific studies from 1990-2020. Iran J Public Health. 2021;50:2397–410.

[61] WHO (World Health Organization). Coronavirus (COVID-19) Dashboard: World Health Organization; 2022. Available at: https://covid19.who.int/. [access date Jun 6, 2022].

[62] Liao KY, Wang YH, Li HC, et al. COVID-19 publications in family medicine journals in 2020: a PubMed-based bibliometric analysis. Int J Environ Res Public Health. 2021;18:7748.

[63] Ammar A, Brach M, Trabelsi K, et al. Effects of COVID-19 home confinement on physical activity and eating behaviour Preliminary results of the ECLB-COVID19 international online-survey. Nutrients. 2020;12:1583.

[64] Brooks SK, Webster RK, Smith LE, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. Lancet. 2020;395:912–20.

[65] Tylka TL, Homan KJ. Exercise motives and positive body image in physically active college women and men: exploring an expanded acceptance model of intuitive eating. Body Image. 2015;15:90–7.

[66] Abeza G, O'Reilly N, Séguin B, et al. Social media scholarship in sport management research: a critical review. J Sport Manage. 2015;29:601–18.

[67] Hayes M. Social media and inspiring physical activity during COVID-19 and beyond. Manag Sport Leis. 2022;27:14–21.

[68] Yang H, Ma J. Post-COVID-19 distress and unhealthy behavior. J Mental Health. 2022:1–6.

[69] Szpunar M, Bourke M, Vanderloo LM, et al. Parent-reported changes in Ontario children's physical activity levels during the COVID-19 pandemic. Children. 2023;10:221.

[70] Katewongsa P, Widyastari DA, Haemathulin N, et al. Recovery shape of physical activity after COVID-19 pandemic. J Sport Health Sci 2023;12:501–12.

[71] Acito M, Rondini T, Gargano G, et al. How the COVID-19 pandemic has affected eating habits and physical activity in breast cancer survivors: the DianaWeb study. J Cancer Surviv. 2022;1:12.

[72] Ng TK, Kwok CK, Ngan GY, et al. Differential impacts of COVID-19 pandemic on physical activity involvements and exercise habits in people with and without chronic diseases: a systematic review and meta-analysis. Arch Phys Med Rehabil. 2022;103:1448–1465.e6.

[73] Oudjedi A, Derouiche M, Allali A, et al. Association between physical activity and sleep quality in Algerian adults during COVID-19 lockdown. Phys Educ Students. 2022;26:18–26.

[74] Tanriverdi A, Savci S, Kahraman BO, et al. Extrapulmonary features of post-COVID-19 patients: muscle function, physical activity, mood, and sleep quality. Ir J Med Sci. 2022;191:969–75.

[75] Calcaterra G, Fanos V, Cataldi L, et al. Need for resuming sports and physical activity for children and adolescents following COVID-19 infection. Sport Sci Health. 2022;18:1179–85.

[76] Ostermeier E, Tucker P, Tobin D, et al. Parents' perceptions of their children's physical activity during the COVID-19 pandemic. BMC Public Health. 2022;22:1459.

[77] Cui D, Zhang X, Guo J. The impact of the COVID-19 pandemic on physical activity and sleep among healthy adults: a systematic review and meta-analysis. Front Psychol. 2023;14.

[78] Rodriguez-Blanco C, Bernal-Utrera C, Anarte-Lazo E, et al. A 14-day therapeutic exercise telerehabilitation protocol of physiotherapy is effective in non-hospitalized post-COVID-19 conditions: a randomized controlled trial. J Clin Med. 2023;12:776.

[79] WHO (World Health Organization). Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19) 2020. Available at: https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-COVID-19-final-report.pdf. [access date Jun 6, 2022].

[80] Sollini M, Ciccarelli M, Cecconi M, et al. Vasculitis changes in COVID-19 survivors with persistent symptoms: an [18 F] FDG-PET/CT study. Eur J Nucl Med Mol Imaging. 2021;48:1460–6.

[81] Piva T, Masotti S, Raisi A, et al. Exercise program for the management of anxiety and depression in adults and elderly subjects: Is it applicable to patients with post-covid-19 condition? A systematic review and meta-analysis. J Affect Disord. 2023;325:273–81.

[82] Costa BOD, Andrade LS, Botton CE, et al. Effects of a telehealth stretching exercise program on pain, sleep, depression, and functionality of women with fibromyalgia during the COVID-19 pandemic: a randomized clinical trial. Sustainability. 2023;15:2604.

[83] Zhao Y, Wang W, Wang M, et al. Personalized individual-based exercise prescriptions are effective in treating depressive symptoms of college students during the COVID-19: a randomized controlled trial in China. Front Psychiatry. 2023;13:1015725.

[84] Stanaway JD, Afshin A, Gakidou E, et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018;392:1923–94.

[85] Rawat D, Dixit V, Gulati S, et al. Impact of COVID-19 outbreak on lifestyle behaviour: a review of studies published in India. Diabetes Metab Syndr. 2021;15:331–6.

[86] Cava MA, Fay KE, Beanlands HJ, et al. The experience of quarantine for individuals affected by SARS in Toronto. Public Health Nurs. 2005;22:398–406.

[87] Tan W-K, Lu K-J. Smartphone use at tourist destinations: Interaction with social loneliness, aesthetic scope, leisure boredom, and trip satisfaction. Telemat Inform. 2019;39:64–74.

[88] Kil N, Kim J, Park J, et al. Leisure boredom, leisure challenge, smartphone use, and emotional distress among US college students: are they interrelated? Leisure Studies. 2021;40:779–92.

[89] Wang W-C. Exploring the relationship among free-time management, leisure boredom, and internet addiction in undergraduates in Taiwan. Psychol Rep. 2019;122:1651–65.

[90] Rad D, Balas VE, Demeter E, et al. Chapter 9: The emerging association between boredom, COVID-19 anxiety, and aggressiveness in imposed prolonged social isolation. In: Balas VE, Geman O, eds. Biomedical Engineering Applications for People with Disabilities and the Elderly in the COVID-19 Pandemic and Beyond. 1th ed. Elsevier;2022:85–92.

[91] Mehmood K, Mushtaq S, Bao Y, et al. The impact of COVID-19 pandemic on air pollution: a global research framework, challenges, and future perspectives. Environ Sci Pollut Res. 2022;29:52618–34.