Title: Effects of the COVID-19 Pandemic on Physical Activity in Children: A Systematic Review

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Discussion Points:

- What affected physical activity in children and adolescents during the COVID-19 pandemic?
- What strategies could have been employed to encourage children and adolescents to participate in more physical activity during the COVID-19 pandemic?

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ABSTRACT.

Background: Extended lockdowns established to minimize the spread of COVID-19, may have affected physical activity (PA). The objective of this systematic review was to report how PA of children was impacted by the COVID-19 pandemic.

Methods: A database search of CINAHOL, Embase, MEDLINE, PsycInfo, and Web of Science was conducted on 03/29/2021 in accordance with Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. Studies were included if they reported a measure of PA for children ≤18 years and were published in English in a peer-reviewed journal. The search generated 673 unique citations. After applying the criteria above, 69 articles were included. The quality of the included articles was assessed using the NIH NHLBI Study Quality Assessment Toolbox.

Results: Unstructured play, walking, and virtual PA (e.g., YouTube, online classes) were the most frequently reported modes of PA during the COVID-19 pandemic. The PA of children decreased among 89% of articles that reported changes in PA (e.g., frequency, intensity, duration, or the percentage of children who met PA recommendations) of children during the COVID-19 pandemic. Increased PA was reported more often among younger children, boys, children who lived with other children, and children with more outdoor space.

Conclusion: Globally, PA of children decreased during the COVID-19 pandemic. Further work is needed to develop policies to support global PA increases. Limitations of this review include the use of online surveys which are limited by participants ability to recall PA behaviors and access to online resources.

Key Words: COVID-19, exercise, children

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INTRODUCTION.

The COVID-19 pandemic (the pandemic) and its effects rapidly permeated the globe with over 100 million cases by February 1st, 2020.[1] By March 2020, many governments issued stay-at home orders, shelter-in-place orders, lockdowns, and various social-distancing guidelines to mitigate the spread of COVID-19.[2] These restrictions, including the closure of schools, parks, and organized sports, may have altered movement behaviors, including physical activity (PA).[3,4] PA in children encompasses a variety of modes (e.g., exercise, sports, and active play).[5] PA has been defined as any body movement that increases energy expenditure and can be characterized by the components of the FITT principle: frequency, intensity, time (e.g., duration), and type.[6] The WHO recommends children (ages 5-17) engage in ≥60 min/day of moderate-to-vigorous (MVPA) intensity PA[7] where 3 days/week include vigorous-intensity aerobic activities, muscle-strengthening and bone-strengthening activities.[8] As a critical component of child development, PA has substantial long-term health benefits including the prevention of chronic health conditions.[9,10] Conversely, insufficient PA in children can increase the risk of developing cancer, heart disease, obesity, and type 2 diabetes.[11] Despite the known benefits of PA on health, global levels of PA were insufficient in 4 out of 5 children prior to the pandemic.[12] Thus, the prolonged stay-at-home orders brought on by the pandemic may have exacerbated the proportion of children with insufficient PA, as previous studies have shown that children have less PA when they are out of school (e.g., holidays, summer, weekends).[13,14] Although children seem to have a lower risk of contracting COVID-19,[15,16] the physical health burden of the pandemic and the resulting restrictions are of increasing interest.[1,17,18]

Previous studies have demonstrated that childhood health behaviors, including PA, are likely to persist through adulthood and can impact lifetime health.[19,20] It is important to monitor PA changes in children to reduce the risk of developing long-term health consequences associated with inadequate PA (e.g., cardiovascular disease, type 2 diabetes, obesity).[21,22] Not only can PA prevent many chronic diseases,[23] but it can also have acute health benefits such as boosting the immune system.[24,25] A recent study in adults infected with COVID-19, found reduced risk of critical outcomes in individuals who routinely adhered to PA recommendations.[26] Although this relationship has not yet been established in children, several studies have found obesity to be the most prevalent characteristic in children infected with COVID-19.[27,28] The disruption of PA in children may increase the prevalence of childhood obesity and other comorbidities which could, in turn, increase the risk of infection and subsequent severity in outcomes from COVID-19.[15,29]

As childhood is a critical period of development, understanding the implications of the pandemic on health behaviors is important and there is a need to highlight potential adverse effects that may need to be actively monitored and remediated as COVID-19 restrictions lift and vaccines are distributed.

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Identifying changes in PA (FITT principle) of children is important for understanding the extent to which the pandemic impacted already low levels of global PA among children. In addition, recognizing the biological, social, and environmental factors that affected changes in PA is critical for the development of effective programs to prevent short- and long-term health consequences. To the authors' knowledge, this is the first review to synthesize the literature at the time of the data search regarding the global impact of the pandemic on the duration and types of PA children participated in and what biological, social, and environmental factors contributed to those changes. The goal of this review was to synthesize the global impact of the pandemic on PA of children by addressing the following questions:

1) What types of PA did children participate?

2) To what extent did PA (e.g., duration of PA, percentage of children meeting PA recommendations) of children change?

3) What biological, social, and environmental factors affected changes in PA of children?

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METHODS

This review was conducted using the PRISMA guidelines.[30] The selection process for the included articles is summarized in **Figure 1**.

2.1 Search Strategy

Two research librarians independently searched MEDLINE, Embase, PsycInfo, CINAHOL, and Web of Science on 03/29/2021. The searches were limited to the English language, COVID-19, and 2020-current (03/29/2021). The key words used in the search strategy included various combinations of terms such as: “physical activity,” “exercise,” “activity level,” or “sports” AND “child,” “adolescent,” “girl,” “boy,” or “youth” AND “covid-19,” “severe acute respiratory syndrome coronavirus 2” or “'sars-cov-2”. Following their independent searches, the librarians compared results and removed duplicates.

2.2 Article Inclusion and Exclusion Criteria

Included studies were those that were published in English in a peer-reviewed journal, included a measure of PA during the pandemic, and encompassed PA data for children ≤18 years. Articles were excluded if they did not present original empirical findings, if they described the development of a tool or measure, or if they were inaccessible to the authors (e.g., no free full-text download was available).

2.3 Article Selection

After the librarians removed any duplicate articles, 673 articles remained. The following article selection process was conducted in 4 steps. First, 2 authors conducted an independent abstract review to determine whether each article should be included or not based on the inclusion and exclusion criteria. Second, the 2 authors discussed any articles they disagreed on until consensus. Following this discussion, 572 articles were excluded because they had a study population outside the context of the current review, meaning that PA data presented in the findings were not specified for participants ≤18 years old. Third, the full text of the remaining 101 articles was reviewed to ensure the articles were within the scope. The data extracted included authors, year of publication, sample source (e.g., the country the sample was gathered from), sample size, sample age range, PA measure, main findings, and factors (e.g., biological, social, and environment) related to PA and are outlined in **Table 1**. Ultimately, 32 of these articles were excluded because they met ≥1 exclusion criteria. In the fourth step, all authors met to confirm the final 69 articles should be included. The data from the 69 articles was synthesized into a table adapted from a review paper of a similar topic (**Table 1**).[31]

2.4 Quality Assessment

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The quality of the included articles was assessed using the NIH NHLBI Study Quality Assessment Toolbox.[32] This quality assessment tool describes a “good” study as one with a low risk of bias and a “fair” study as one with some bias.[32]

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RESULTS.

3.1 General Characteristics

General characteristics of the included articles are shown in **Table 2**. Most articles included participants in Europe (n=34),[33-66] North America (n=13),[67-79] or South America (n=6).[49,58,80-83] The distribution of countries represented by the articles in this review are depicted in a heat map in **Figure 2**. The sample sizes ranged from 9 children[76]-16177 parents.[84] Most articles (n=32) [33-35,38-41,43,47,48,50,51,58,60,62,63,67,70,71,74,75,81,82,85-93] had a sample size between 100-1000, but 2 articles had a sample size >10000.[77,84] As the present study is focused on children, most of the articles are inclusive of age groups between 0-18 years. However, 5 articles included participants ≤age 19 because the articles specified their sample as either adolescents (n=4)[58,76,77,89] or school-aged youth (n=1).[74] Because adolescents are defined by the WHO as individuals 10-19 years old,[94] these articles were included despite the exclusion criteria of ≤18 years. One article did not specify the age of participants,[78] however, specified participants were in grades 3-12, and was ultimately included. Most participants were children without chronic health conditions, but some articles focused on characterizing PA during the pandemic for children with various health conditions (e.g., autism spectrum disorder, congenital heart disease, chronic respiratory disorders, obesity, type 1 diabetes, attention-deficit/hyperactivity disorder; n=11).[52,54,56,63,66,70,76,85,88,92,95] Some articles examined PA during the pandemic only (n=13),[35,45,55,57,61,68,69,77,82,86,91,93,96] while others compared PA from before to during the pandemic (n=56).[33,34,36-44,46-54,56,58-60,62-67,70-76,78-81,83-85,87-90,92,95,97-102] PA was reported by either the child (n=28),[38-41,43,48,52,56,58-62,64,68,74,76,77,80,86,89,91,96,97,99-102] the parent or guardian (n=32),[34,35,37,42,44,47,49-51,53-55,63,66,67,69,71-73,75,79,81-85,87,88,90,92,95,98] a different secondary subjective individual such as a school administrator (n=1),[78] or a combination of these groups (n=5).[36,45,57,65,93] Based on the NIH NHLBI Study Quality Assessment Toolbox,[32] 50 articles received a rating of "good," while 19 articles received a rating of "fair" **(Table 1)**.

3.2 PA Measures

PA measures used in the included articles are depicted in **Table 2**. Online surveys were predominantly used to collect PA data. Common PA questionnaires included the International Physical Activity Questionnaire (IPAQ, short or long form; n=8)[58,63,64,67,80,96,100,102] and the Physical Activity Questionnaire for Adolescents (PAQ-A; n=5)[38-41,101] or for children (PAQ-C; n=2).[44,45] The PAQ-A designates a physical activity level (PAL) based off a scale of 1-5: 1 designating no activity or a low activity level and 5 designating a high activity level. A PAL score below 2.73 suggests an insufficient PAL and a score above 2.73 suggests a sufficient PAL. A few surveys took place in-person (n=2)[43,66] or over the phone (n=4).[37,54,56,95] Seven studies used objective measures to collect PA data, including the use of a Fitbit,[70] accelerometer,[33,37,48,62] smartphone sensors (e.g., pedometer),[89] or a 20-meter shuttle run test to measure VO2 max.[46] The most prevalent FITT principle collected to determine PA was time (e.g., duration of PA; n=46),[33,36,42,45,47,48,50,52-68,71-73,75,76,80-84,86,87,89-93,96-100] followed by frequency (n=30),[38,39,43-

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[45,49,51,52,59,60,63-65,68,69,71,73,74,76,77,79-81,84,90-92,96,102] type of exercise (n=30),[36,38,39,43-45,51,59,60,62,63,68,71-73,75,77-79,84,89-92,95-98,100,102] and intensity (n=25).[33,36,45,48,52,53,59,62-64,67,68,71-74,79,80,84,91,96,97,99,100,102]

3.3 Types of PA

Among the articles included, there were conflicting results concerning the effects of the pandemic on the types of PA in which children participated. Five articles reported that outdoor PA declined during the pandemic,[71-73,95,98] while, in contrast, 3 studies reported that outdoor PA increased.[37,51,90] The types of outdoor PA included activities such as walking, biking, outdoor play, play at parks or other public spaces, and sports. Eight studies reported many children (e.g., 82%)[84] were active at home.[60,61,63,71,75,84,90,95] Some studies reported the use of online platforms such as streaming services (e.g., YouTube), virtual classes (e.g., yoga),[45,75] or other virtual PA forms[79] to accumulate PA during the pandemic.[78,91] In a US study, the most common forms of PA during the pandemic were unstructured play (90%) and walking (55%).[75] In contrast, a Chinese study reported the most common form of PA changed from outdoor activities (e.g., cycling) to indoor activities (e.g., rope skipping).[95]

3.4 Extent to Which PA Changed During the COVID-19 Pandemic

Several studies (n=10) reported most children obtained <30 min/day or <3 hrs/week of PA,[33,35,42,47,56,61,66,68,96,99] with 2 reporting most children participated in PA 0 days/week.[35,68].[99] Of the 12 articles [37,45,49,50,53,57,62,64,69,73,91,99] that reported the percentage of children meeting PA guidelines (i.e., 60 MVPA min/day), 1 article reported <10%,[91] 9 articles reported 10-30%,[45,49,53,57,62,64,69,73,99] and 2 articles reported >50% [37,50] of children met PA recommendations during the pandemic. All articles that utilized the PAQ-A to assess PA(n=5),[38-41,101] reported a significant decrease in PAL.

Of the articles that compared PA before the pandemic to during the pandemic (n=56), [33,34,36-44,46-54,56,58-60,62-67,70-76,78-81,83-85,87-90,92,95,97-102] 89% reported a decrease in PA (i.e., frequency, intensity, type/duration, type) of children. Among these articles, the proportion of participants who reported a decrease in PA behaviors during the pandemic ranged from 42%[43]- 95%.[48] One study reported that although the total minutes of PA/week did not significantly change, the duration and frequency of organized PA decreased, while unstructured PA and outdoor play increased.[90] Similarly, another study found 80.4% of high school students reported their MVPA stayed the same at 1.5 hrs/week.[100] Two studies [37,59] reported an increase in PA (e.g., duration, frequency of meeting PA recommendations/week) of children (n=4), 1 of which reported a specific increase in outdoor time compared to before the pandemic.[37] One study reported 90.3% of preschoolers (3- 5 years old) met PA guidelines of ≤180 minutes of PA/day, with 60 minutes of MVPA/day.[37] The articles that reported PA (e.g., duration, frequency of meeting PA recommendations per week) increased during the pandemic had samples from Sweden,[37] Canada,[71] and Germany.[59,65] However, 4 studies from Canada,[67,70,72,73] 4 studies from Australia,[84,88,89,92] and 1 study from Germany[43] reported PA (e.g., frequency, intensity, daily steps,

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meeting PA recommendations) decreased. For studies that included children with pre-existing health conditions (n=11),[52,54,56,63,66,70,76,85,88,92,95] PA (e.g., daily steps, duration, frequency) decreased compared to before the pandemic. For example, among children with obesity in Italy, sports participation decreased by 2.30±4.60 hrs/week (p=0.003).[54]

3.5 Biological, Environmental, and Social Factors Affecting PA During the COVID-19 Pandemic

Common trends were evident among the studies of this review that related factors such as gender, age, and the environment outside as well as inside the home to the PA of children during the pandemic. In general, boys had higher levels of PA (e.g., more minutes of PA/day or more likely to meet PA recommendations) than girls. A study in Tunisia found that total PA (score from the Ricci and Gagnon sedentary behavior questionnaire based on duration and intensity of PA) decreased by 17% and 7% among girls and boys, respectively and. [97] Older children tended to have greater reductions in time/duration of PA compared to younger children. For example, in 2 Spanish studies, PA decreased an average of 43.3 min/day among preschoolers aged 4- 6 years old,[33] while PA decreased an average of 91 ± 55 min/day among older children aged 8- 16 years old.[48] There were mixed results for PA of children and parents' socioeconomic status (e.g., lower levels of PA were reported almost equally for both high and low parental income and education). Children who lived in a rural area [83] or had more outdoor space to play [36,48,55,82] had lower reductions in PA (e.g., duration, less likely to report decreased PA, greater percentage of day spent participating in PA). For example, children with access to an outdoor area at home had a 1.4 ± 0.1 hrs/day reduction in PA compared to a 1.7 ± 0.1 hrs/day reduction in children without access (p<.01).[48] In contrast, children who lived in a high-density neighborhood [72] or urban area[36,41] had greater reductions in PA (e.g., more likely to report decreased PA, less likely to meet PA recommendations, greater reduction in PAL). Children who lived in an apartment had lower levels of PA (e.g., decrease in duration of PA or less likely to meet PA recommendations) compared to children who lived in a house.[72,83] The environment inside the home also seemed to affect PA of children during the pandemic. One study reported that children who lived in a home with more people had greater reductions in duration of PA,[83] while 3 studies reported children who lived in multi-child households (e.g., with siblings) participated in more PA (e.g., greater duration or greater percentage of day spent participating in PA)[55,83] or more frequent outdoor play.[51,72] Children who had less family conflict, more parental support, and more family engagement in PA had greater durations of PA.[53,73,76] However, children who had more conflict with their parents or who had parents with higher stress levels had less PA (e.g., shorter duration of PA or less likely to achieve a sufficient PAL).[38,53]

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DISCUSSION.

The present study aimed to address the types of PA children participated in, the extent to which PA (e.g., frequency, intensity, duration, and type) changed, and factors affecting PA during the pandemic. Schools, active transportation (e.g., walking to and from school), afterschool programs, and sport programs were predominant sources of MVPA prior to the pandemic.[103,104] The stay-at-home orders and social distancing policies put in place to mitigate the spread of COVID-19 restricted the ability of children to obtain PA through these previously popular sources. While the studies in this review revealed walking, outdoor activity, and activity at home were types of PA children engaged in during the pandemic, a study before the pandemic found that children are less likely to participate in routine PA (e.g., going to the gym, walking) compared to unstructured play.[5] Social distancing restrictions could have contributed to shorter durations of PA and overall decreased participation, despite walking becoming a common source of PA during the pandemic.[75] In addition, some studies reported many children were active at home (e.g., indoors or not at a park/public space).[60,61,63,71,75,84,90,95] Studies before the pandemic have found that indoor PA (e.g., at home, at school) tends to be a greater source of lighter intensity PA,[103] which could help to explain the reduction in children able to meet MVPA recommendations during the pandemic.

The results of this review suggested that while there was heterogeneity in the extent to which the pandemic affected PA (e.g., frequency, intensity, duration, and type) in children, overall, there was a decrease in PA of children globally. Although the impact of the pandemic on PA of children is still evolving, trends before the pandemic have shown children have lower levels of PA when they are not in school.[13,14] Studies that investigated changes in MVPA during time out of school (e.g., weekends or a 3-week school break) found that MVPA decreased by 10-14 minutes compared to week days during the school year.[13,105] In contrast, the reductions in PA presented by the studies in this review ranged from 32-91 min/day.[33,48,54,83,99] These results revealed that the decreases in time/duration of PA during the pandemic may have been greater than those typically observed during days when children are not in school. Prior to the pandemic, global PA levels of children were already low, with 81% of children insufficiently physically active.[12] Of the studies that reported a decrease in PA during the pandemic, the percentage of children who did not meet PA recommendations ranged from 80%- 99.7%.[45,49,62,69,73,91] This suggests that global levels of PA in children may have worsened during the pandemic.

The results of the current study indicate that during the pandemic, boys, and younger children tended to have higher levels of PA (e.g., more likely to meet PA recommendations), which is consistent with PA trends that existed prior to the pandemic.[104,106-109] Previous studies have found that self-efficacy is an important predictor of PA.[108,110] Not only are girls less likely to participate in PA,[111] but they also tend to have a lower perceived ability to overcome PA barriers.[112] The social cognitive theory suggests that self-efficacy moderates the relationship between the social and physical environment and changes in PA,

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such that individuals with a high self-efficacy for overcoming PA barriers should be more likely to participate PA despite changes in the environment.[113] With the changes in the social and physical environment surrounding children during the pandemic, self-efficacy for overcoming PA barriers may have played a role in the observed changes in PA. Similarly, lower levels of self-efficacy in girls may also be due to lower levels of social support to participate in PA compared to boys.[111]

The relationship between self-efficacy, social support, and PA may also apply to age-related changes in PA. Several studies prior to the pandemic reported that children and adolescents with higher levels of peer and family support had higher levels of PA (e.g., frequency, more likely to meet PA recommendations).[5,114-116] For example, 1 study found that adolescents with higher parental support were 40% more likely to achieve sufficient PA (60 minutes of MVPA/day).[115] While it has been established that PA (e.g., proportion of children meeting PA recommendations) decreases with age,[117-120] 1 such study reported that adolescents with greater self-efficacy had lower age-related reductions in PA.[118] The benefits of social support on child PA behaviors could have been especially critical in providing additional support to children navigating barriers to PA during the pandemic. In addition, a past study also found that older girls prefer to do PA at school or in a community setting than at home and participate in team sports.[121]

The changes in PA behaviors during the pandemic were likely due to the intersectionality of many social factors that resulted in decreased PA (e.g., frequency, intensity, duration), especially among girls and older children. Greater participation in PA among children with greater social support could also explain why children living in multi-child home had higher levels of PA (e.g., frequency, duration) during the pandemic. Studies before the pandemic have shown that children with siblings or other children to play with participated in more spontaneous and unstructured play.[122-124] More children inside the home may have been a protective factor for PA in children during the pandemic, as it could have offered greater opportunities and incitement to participate in PA.

The studies in this review suggested that during the pandemic, children in rural areas had lower reductions in PA (e.g., duration) compared to children in urban areas. While some studies before the pandemic have shown MVPA of children was higher in environments with less urbanization,[125,126] 1 study suggested children in suburban or rural areas have less PA.[110] The inconclusive relationship between rurality and PA in children could be due to the lack of a global definition of rurality and different distributions of built environments that are conducive to PA in different countries. A study of low- and medium-income countries in Africa found that urban development led to changes in the environment that were less favorable for outdoor PA.[127] While outdoor time has been shown to be positively related to PA,[128-130] rural environments do not guarantee higher levels of outdoor time. Instead, rural environments may also create barriers to PA such as limited quantity of and access to resources that promote PA, such

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as playgrounds, parks, trails, and other recreational areas. One study found that differences in MVPA between children in rural and non-rural areas of the U.S. were mediated by differences in neighborhood resources.[131] Rather than comparing PA levels by rurality, more general characteristics of the PA environment such as quantity of and accessibility to community recreational areas, neighborhood safety, traffic levels, and walkability may be more helpful in identifying global factors that affected PA in children during the pandemic.

In conclusion, the purpose of the present review was to synthesize the global impact of the pandemic on PA of children. This review adds to the current body of literature on the effects of the pandemic on PA by specifying changes in the frequency, intensity, duration, and type of PA performed by children, as well as the proportion of children who met PA recommendations. The greatest strength of this systematic review is the range of PA data presented for a wide geographic distribution. Information about different changes in PA (e.g., frequency, intensity, duration, type), as well as characterizations of PA during the pandemic may help to create a succinct picture of the impact of the pandemic on PA in children. A limitation of the systematic review process is some relevant studies may have been missed in the database search due to database selection and exclusion of studies not published in English. In addition, the use of online surveys, the most frequent data-collecting method used in the included studies, is an important limitation of this review, as surveys can only report subjective measures of PA. Furthermore, studies that asked participants to recall PA behaviors prior to the pandemic could be inaccurate. Moreover, online surveys may not have been accessible to individuals of low socioeconomic status who may not have access to the internet. Limited representation of individuals of low socioeconomic status could, therefore, affect the generalizability of the results of this review.

While many PA trends that existed prior to the pandemic persisted, the further reductions in already low global PA levels in children is worrisome. As the world reopens and vaccines are distributed, it is important to determine whether these PA trends will persist and for how long. Following a natural disaster in East Japan in 2011, significantly decreased child PA levels persisted more than 3 years later.[132] Consistently insufficient levels of PA in children around the world may have detrimental effects on overall population health. The results of this review may be helpful in identifying barriers and facilitators to PA in children during the pandemic to determine what policies and programs would be most effective at increasing PA of children after the pandemic and beyond.

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SUMMARY - ACCELERATING TRANSLATION

The goal of “Effects of the COVID-19 Pandemic on Physical Activity in Children: A Systematic Review” was to synthesize the global impact of the COVID-19 pandemic on physical activity of children. Identifying changes in physical activity of children is important for understanding the extent to which the pandemic has affected already low levels of global physical activity among children. In addition, recognizing the biological, social, and environmental factors that affected changes in physical activity is critical for the development of effective programs to prevent short- and long-term health consequences. To the authors’ knowledge, this is the first review to summarize the literature at the time of the data search regarding the global impact of the pandemic on the duration and types of physical activity children participated in and what biological, social, and environmental factors contributed to those changes. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines were used to conduct a database search on 03/29/2021. Included studies were peer- reviewed, in English language, and included both a measure of physical activity during the COVID-19 pandemic and physical activity data for children aged 18 and younger. The search yielded 673 unique citations and, ultimately, 69 articles were included in the review. The results of the study found that during the COVID-19 pandemic, frequently reported physical activity included walking, unstructured play, and virtual physical activity through online platforms. Of the articles that reported changes in physical activity of children during the COVID-19 pandemic, 89% reported physical activity (e.g., frequency, intensity, duration, or the percentage of children who met physical activity recommendations) of children decreased. Boys, younger children, children who lived with other children, and children with more outdoor play space had higher levels of physical activity. From these results, it was concluded that the COVID-19 pandemic resulted in decreased physical activity among children around the world. The results of this review may be helpful in identifying barriers and facilitators to physical activity in children during the COVID-19 pandemic. Future work in policy and program development is needed to target physical activity of children beyond the COVID-19 pandemic.

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FIGURES AND TABLES.

Figure 1. Article Selection Diagram Using PRISMA.

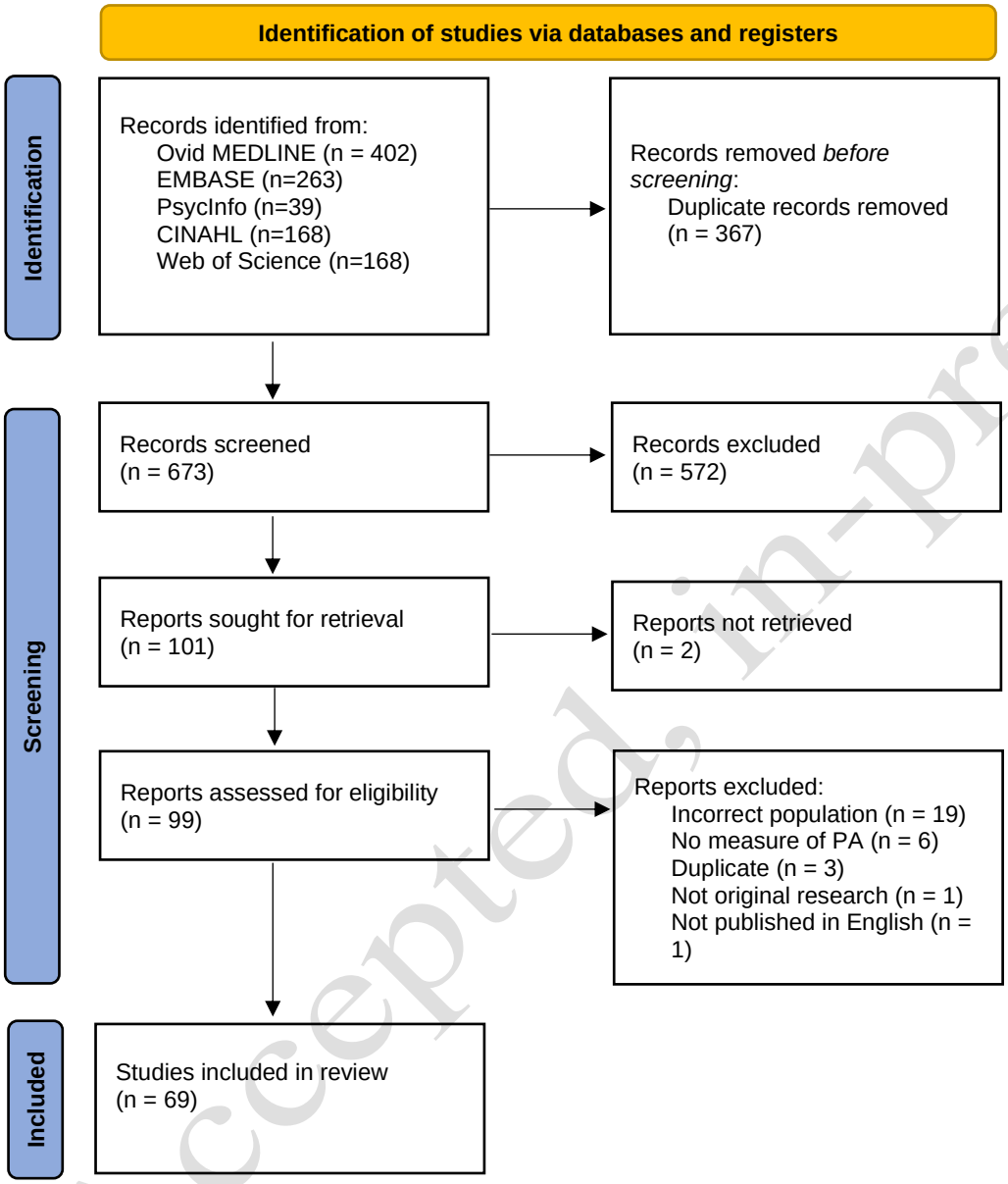

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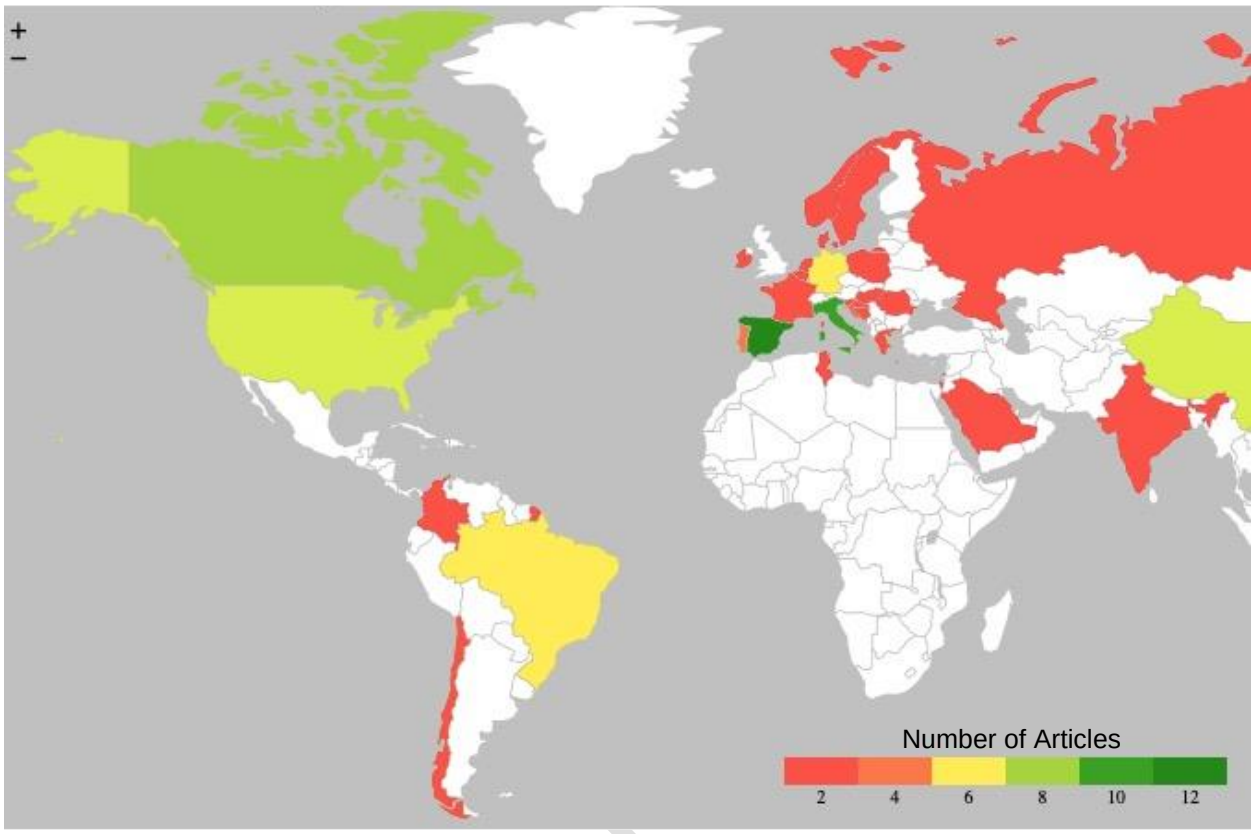
Figure 2. Sample Source (Countries) of Included Articles.



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1 **Table 1**. Characteristics of Included Articles (N=69) and Effects of the COVID-19 Pandemic on Physical Activity
2 (PA) and Biological, Environmental, and Social Factors that Affected PA.

Article Number	Author (Year)	PA Measure;PA Data Reported by[a]	Sample Source (Country)	Sample Size	Age Ranges	Findings	Biological, Environmental, and Social Factors that Affected PA	NIH NHLBI Study Quality Assessment
34	Alonso-Martinez (2021)	Wrist-worn GENEActiv tri-axial accelerometer	Spain	Before the COVID-19 pandemic: 268 children During the COVID-19 pandemic: 145, March to April 2020; device-measured PA n=21 children	4-6	On average, preschoolers had 43.3 minutes less/day (95% confidence interval (CI) −68.1 to −18.5 (p=.002)) of total PA during the COVID-19 pandemic. MVPA also decreased an average of 17 min/day (p<0.001).	Children who met PA recommendations had lower internalizing scores (i.e. social withdrawal, shyness, anxiety).	Good
35	Androutsos (2021)	Online survey; 2	Greece	397 children	2-18	During lockdown, 66.9% of parents reported their child's PA level decreased.	Decreased PA was associated with body weight increase (p<0.001).	Good
36	Cachon-Zagalaz (2021)	Online survey; 2	Spain	837 children	0-12	The highest percentage of participants (34%) spent 0 days/week on PA during lockdown, followed by 32.6% for 2-3 days/week, 19.6% for 4-5days/week, and 13% for 6-7 days/week.	Children with an established routine/schedule (M = 38.13; SD = 35.01) and children in the 6 to 12 years old age group (M = 38.95; SD = 30.25) reported higher levels of daily PA. 34.8% of the sample reported 0 days/week of PA during the COVID-19 pandemic.	Good
37	Chambonniere (2021)	Online survey; 1,2	France	6491 children	6-17	During lockdown, PA decreased for 42% of children, stayed the same for 21.3% of children, and increased for 36.7% of children. Similarly, PA decreased for 58.7%, stayed the same for 21.8%, and increased for 19.6% of adolescents.	PA decreased among 35.2% of children in rural areas, 46.7% of children in suburban areas, and 47.9% of children in urban areas (PA was significantly associated with geographic location p<0.001). Living in an urban environment was associated with a decrease in PA (p<0.001). Among children without access to an outdoor area, 64.2% reported decreased PA, while among children with access to an outdoor area, only 37.8% reported decrease PA during the COVID-19 pandemic (p<0.001). The proportion of participants who increased, decreased or did not change their PAL during the lockdown was significantly associated with gender in adolescents (p<0.001) but not in children (p=0.10). Childre n and	Good

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							adolescents who were more active prior to the COVID-19 pandemic had greater reductions in PA compared to those who were initially less active (p>0.001).	
38	Delisle (2020)	Telephone questionnaire ; 2	Sweden	100 children	3-5	PA (+53 min/day) and outdoor time on weekdays (+124 min/day) and weekends (+68 min/day) significantly increased (all p-values ≤ 0.001). PA guidelines were met by 90.3% (n = 65) of the children.	Boys had higher levels of PA (262.5 ± 60.3 vs. 220.4 ± 39.2 min, p = 0.002), MVPA (136.9 ± 43.8 vs. 107.8 ± 29.2 min, p = 0.004), and vigorous PA (39.0 ± 19.4 vs. 29.4 ± 15.7 min, p = 0.028) compared to girls. However, gender was not significantly associated with meeting PA recommendations .	Good
39	Gilic, B., et al. (2020).	PAQ-A; 1	Bosnia and Herzegovin a	688 children	15-18	Compared to before the COVID-19 pandemic, the PAL of the entire sample decreased (from 2.98 ± 0.71 to 2.31 ± 0.68; t-test: 11.88, p < 0.001), as well as among girls (2.69 ± 0.49 to 1.95 ± 0.56; t-test: 8.88, p < 0.001) and boys (from 3.12 ± 0.56 to 2.50 ± 0.44; t-test: 10.01, p < 0.01).	Boys were more likely to achieve a sufficient PAL during the COVID-19 pandemic (OR: 2.41, 95%CI: 1.11–4.01). Higher paternal education was associated with a greater likelihood of achieving a sufficient PAL during the COVID-19 pandemic (OR: 1.33, 95%CI: 1.19–2.01). In contrast, children with more parental/family conflict had a lower likelihood of achieving a sufficient PAL (OR: 0.77, 95%CI: 0.60–0.99).	Good
40	Gilic, B., et al. (2021).	PAQ-A; 1	Bosnia and Herzegovin a	661 children	15-18	67% of boys and 28% of girls (48% overall) had a sufficient PAL before the COVID-19 pandemic, while 37% of boys and 9% of girls (24% overall) had a sufficient PAL during the COVID-19 pandemic (April 2020).	Children with a sufficient PAL during the COVID-19 pandemic had higher participation in individual and team sports prior to the COVID-19 pandemic (MWZ: 6.65, 7.95, respectively, all p < 0.01).	Good
41	Sekulic, D., et al. (2020).	PAQ-A; 1	Croatia	388 children	15-18	There was a significant decrease in PAL of children from before to during the COVID-19 pandemic (2.99 ± 0.70 and 2.67 ± 0.60 for PAL-BL and PAL-FU, respectively; t-test = 3.46, p < 0.001).	The decrease in PAL of boys (3.10 ± 0.78 and 2.79 ± 0.82 for PAL-BL and PAL-FU, respectively; t-test = 5.15, p < 0.001), but not girls (2.71 ± 0.66 and 2.59 ±0.90, respectively; t-test = 0.61, p > 0.05) was statistically significant. Boys had significantly	Good

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							higher PALs than girls during the COVID-19 pandemic (t-test = 2.11, p < 0.05), with	
42	Zenic, N., et al. (2020).	PAQ-A; 1	Croatia	823 children	14-18	PAL decreased among the entire sample (from 2.97±0.61 to 2.63±0.68,p<0.01) as well as for urban adolescents (from 3.11±0.64 to 2.68±0.67,p<0.001).	Children who lived in urban areas had greater reductions in PA level.	Good
43	Francisco, R., et al. (2020).	Online survey; 2	Italy, Spain, and Portugal.	1480 children	3-18	During the COVID-19 pandemic, most children experienced <30 min of PA daily (53%) compared to 30 to 60 minutes daily before the COVID-19 pandemic (33.1%). The changes in PA from before to during quarantine were significant for the entire sample (z = −25.56, p < 0.001, r = 0.66) as well as for each country (Italy: z = −16.08, p < 0.001, r = 0.60; Spain: z = −15.45, p < 0.001, r = 0.74; Portugal: z = −12.48, p < 0.001, r = 0.66).	Not reported.	Good
44	Hommes, F., et al. (2021).	Questionnaire; 1	Germany	385 children	8-18	42.2% of primary school students (8 to 13 years old) reported decreased PA during the COVID-19 pandemic.	A greater proportion of primary school students (8 to 13 years old) reported decreased PA than secondary school students (13 to 18 years old) during the COVID-19 pandemic.	Good
45	Konstantinou, C., et al. (2021).	PAQ-C; 2	Greece	1509 children	5-14	Compared to before the COVID-19 pandemic, children's PA decreased in school and out of school after schools were re-opened (p<0.001). The frequency of activities (i.e., sports, cycling, dance) children engaged with also decreased compared to before the COVID-19 pandemic (post-COVID-19 pandemic: median [Q1, Q3]: 1.38 [1.25, 1.62]) vs. pre-COVID-19 pandemic: 1.5 [1.38, 1.75]).	Not reported.	Fair
46	Kovacs Va Md, P., et al. (2021).	PAQ-C; 1, 2	Russian Federation, Spain, Italy, Germany, France, Belgium, Portugal, Romania, Hungary, Poland, and Slovenia	8395 children	6-18	Among the entire sample, children met PA guidelines an average of 4 days/week and 19% of children met the 60 minutes of moderate-to-vigorous PA/day guideline during the COVID-19 pandemic. However, most countries, individually, had < 20% of children able to meet PA recommendations (range of 7.5% to 26.7%). Slovenia and Romania had the greatest proportion of children able to meet PA recommendations (26.7% and 23.5%) as well as the greatest proportion of children playing outside for more than 2 hrs/day (56.1% and 66.3%). During the COVID-19 pandemic, 56.6% of children were active in online P.E..	In countries mildly affected by the COVID-19 pandemic (Germany, Romania, Poland, Slovenia, and Hungary), children were more likely to meet PA recommendations if they had a structured daily routine (OR = 1.62 [95%CI, 1.24–2.13]). Children were also more likely to meet PA recommendations if they played outdoors for more than 2 hrs/day, however this relationship was more predominant among older children (OR =	Good

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							2.56 [95%CI, 1.98–3.32]). Among older children in countries strongly affected by the COVID-19 pandemic (Spain, Italy, France, Russia, Portugal), children who participated in online P.E. were more likely to have higher levels of PA (OR = 1.27 [95%CI, 1.12–1.44]).	
47	Lopez-Bueno, R., et al. (2021).	VO2 (20m shuttle run)	Spain	89 children	12-14	The average VO2 max of the sample decreased 0.5 ml.kg−1.min−1 (SD 0.3) (p = 0.12) from before to after the COVID-19 pandemic (before: 46.2 ml.kg−1.min−1 (SD 0.6), after: 45.7 ml.kg−1.min−1 (SD 0.7)). The greatest reduction in VO2 max was reported for 14-year-old girls, with a reduction of 1.5 ml.kg−1.min−1 (SD 0.6) (p=0.02).	Not reported.	Good
48	Lopez-Bueno, R., et al. (2020).	Online survey; 2	Spain	860 children	3-16	PA decreased for all gender and age groups from before to during the COVID-19 pandemic, with an average of 96.1 minutes of PA/week during the COVID-19 pandemic compared to 198.6 (SD 180.9) minutes of PA/week before (-102.5 minutes/week). The greatest reduction in PA was among 6- to 12-year-old children with a reduction of 120.4 (SD 159.0) min/week.	Boys and younger children participated in the most weekly minutes of PA (211.9 (SD 188.4) and 223.0 (SD198.0) min/wk).	Good
49	Medrano, M., et al. (2021).	"The Youth Activity Profile" questionnaire (YAP); 1	Spain	113 children	8-16	Children participated in PA an average of 63 (SD 39) min/day during the COVID-19 pandemic, with an average decrease in PA of 91 ± 55 min/day (P < .001) compared to before the COVID-19 pandemic. Decreased PA was reported among 95.2% of children during the COVID-19 pandemic.	Children of mothers with a higher education level had smaller reductions in PA during the COVID-19 pandemic (−1.3 ± 0.1 hour/day vs −1.7 ± 0.1 hour/day, P < .005). Children with access to an outdoor area at home or a large indoor space (i.e. attic or garage) also had lower reductions in PA compared to children without access. (−1.4 ± 0.1 h/d vs −1.7 ± 0.1 h/d, P < .01).	Good
50	Lopez-Gil, J. F., et al. (2021)	Online survey; 2	Spain and Brazil	1099 children	3-17	Compared to before the COVID-19 pandemic, Spanish and Brazilian children engaged in less days of PA/week during the COVID-19 pandemic (p<0.001, p<0.001). Before the COVID-19 pandemic, 34.6% of Spanish children and 30.6% of Brazilian children met PA recommendations. During the COVID-19 pandemic, 26.5% of Spanish children and 21.8% of Brazilian children met PA recommendations.	Not reported.	Good

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51	Morgul, E., et al. (2020).	Online survey; 2	UK	927 caregivers	5-11	Daily PA of children significantly decreased during the COVID-19 pandemic (x2 (15, n=927) = 121.26, p < .001). Before the COVID-19 pandemic, 67.3% of children met PA recommendations (at least 60 min of PA/day), while 51.1% of children met PA recommendations during the COVID-19 pandemic.	Not reported.	Good
52	Poulain, T., et al. (2021).	Online questionnaire ; 2	Germany	285 children	1-10	From before the during the COVID-19 pandemic, there was a significant decrease in indoor sports (p=0.001) and an increase in the frequency of outdoor play (before 60%, during 71%).	Lower SES was associated with less frequent outdoor play, while more frequent outdoor play was significantly associated with more children at home (p<0.001).	Fair
53	Ng, K., et al. (2020).	PACE +; 1	Ireland	1214 children	12-18	During the COVID-19 pandemic, 50% of children reported decreased PA, 30% reported no change in PA, and 20% reported increased PA compared to before the COVID-19 pandemic. The most frequently reported barriers to PA included coronavirus and sports cancellation, while facilitators to PA included having nothing else to do, school cancellation, and going on walks.	Children with well-established PA habits before the COVID-19 pandemic were less likely (OR=0.4, CI=0.2–0.6) to report decreased PA, while overweight (OR=1.8, CI=1.2–2.7) or obese (OR=2.2, CI=1.2–4.0) children were more likely to report decreased PA during the COVID-19 pandemic. Furthermore, participation in strength-training exercises a minimum of three times in the past week was strongly associated with higher levels of PA (OR=1.7, CI=1.3–2.4).	Good
54	Orgiles, M., et al. (2020).	Online survey; 2	Italy and Spain	1143 parents	3-18	During lockdown, the time children spent doing PA decreased (β = 0.04, SE = 0.07, Wald $\chi 2$ 95% CI [0.03, 0.04], p < 0.001). For example, the proportion of children who reported < 30 minutes of PA/day increased from 13.6% before the COVID-19 pandemic to 55.6% during the COVID-19 pandemic. Similarly, the proportion of children who met PA recommendations (at least 60 minutes of PA/day) decreased from 54.1% to 14.8%.	Easier family coexistence was associated with a higher duration of exercise in children (ρ = 0.08; p = 0.004). In contrast, children of parents with high stress levels were more likely to have less PA (ρ = −0.10; p ≤ 0.001).	Good
55	Pietrobelli, A., et al. (2020).	Telephone questionnaire ; 2	Italy	41 children	6-18	Among kids with obesity, sports activity decreased by 2.30±4.60 hours/week (p=0.003).	Not reported.	Good
56	Pombo, A., et al. (2020).	Online survey; 2	Portugal	2159 children	0-12	During the COVID-19 pandemic, 0 to 2 year old children had the highest percentages of PA (%PA). (%PA: play with PA (tag, hide and seek, etc.) + PA (organized indoor and outdoor PA) / (intellectual activity + playful screen time + play w/o PA + play w/ PA + PA)).	Outdoor space (p<0.001), the presence of other children in the home (p=0.002), younger age (p<0.001), and having an adult at home not working were significantly associated with higher levels of %PA (P < .001). In contrast, lower levels of %PA in	Good

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							children were associated with families in which all adults worked from home (p=0.016). There was no significant effect of gender on differences in %PA.	
57	Predieri, B., et al. (2020).	Telephone questionnaire ; 1	Italy	62 children	1-18	Among children with type 1 diabetes, time spent on exercise significantly decreased from before to during the COVID-19 pandemic (3.27 ± 2.82 vs. 0.24 ± 0.59 h/week, respectively; p <0.0001).	Not reported.	Good
58	Roe, A., et al. (2020).	Online survey; 2, 3	Norway	5368; 4642 parents, 726 teachers	6-16	About one-third of all participants reported their child participated in more than 60 minutes of daily PA. Students in grades 1-4 (5 to 10 years) had the most PA, with more than 60 minutes of daily PA reported by 43% of parents. In contrast, only 18% of students in grades 8-10 (13 to 16 years) reported more than 60 minutes of daily PA.	Duration of daily PA increased with age of participants. Boys participated in more PA than girls in grades 1-7.	Good
59	Ruiz-Roso, M. B., et al. (2020).	IPAQ; 1	Italy, Spain, Brazil, Chile, and Colombia	726 children	10-19	Before the COVID-19 pandemic, 27% of all participants were physically active compared to 20.5% during the COVID-19 pandemic.	Boys were more active than girls [OR 2.22 (CI 95% 1.28–3.86)] before and during the COVID-19 pandemic. Higher maternal education was associated with lower levels of PA during the COVID-19 pandemic [OR 0.40 (CI 95% 0.20–0.84)].	Good
60	Schmidt, S. C. E., et al. (2020).	MoMo PAQ; 1	Germany	1711 children	4-17	While the duration of organized and nonorganized sports decreased (10.8 min/day, p<0.01), there was an increase in habitual PA (i.e., playing outside, walking, cycling, gardening, housework) (36.2 min/day, p<0.01). The proportion of children who met PA recommendations increased by 11.1% (p<0.01) during the COVID-19 pandemic. Among the entire sample, the number of active days also increased by 0.4 days/week (p<0.01).	Older children (ages 14 to 17) had greater increases in nonorganized sports than younger children (ages 4 to 5) (17.0 vs 11.8 min/day). Older children had greater reductions in total sports than younger children (15.6 vs 2.2 min/day). Younger children had higher levels of habitual PA overall, but also played outside more, while older children walked and cycled more. Boys reported more min/day playing outside, walking, and cycling than girls. The proportion of children who met PA recommendations increase among 14.7% of children aged 4 to 5 compared to only 4.8% of children aged 14 to 17.	Fair

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61	Schmidt, T. and C. S. Pawlowski (2020).	Online survey; 1	Denmark	142 children	15-18	From before to during the COVID-19 pandemic, the average minutes of PA/week decreased by 36.6% ($p<0.001$). Prior to the COVID-19 pandemic, most children reported being physically active 2 to 4 times per week (50.4%), while during the COVID-19 pandemic most children reported being physically active 5 times or more per week (44.9%). The proportion of children who participated in PA 5 times or more per week increased by 19.1%, while the proportion of children who rarely or never did PA increased by 71.8%. Although outdoor activity was still a frequently reported form of PA, less children reported doing street activities and team ball games compared to before to COVID-19 pandemic. 57.1% of children reported doing the most PA at home and 33.3% reported doing the most PA in public. Children were most physically active with family (40.8%) or alone (57.7%) in comparison to with friends (83.5%) before the COVID-19 pandemic.	Not reported.	Good
62	Salzano, G., et al. (2021).	Online survey; 1	Italy	1860 children	12-18	During the COVID-19 pandemic, 84.5% of children participated in PA at home. PA at home was most often practiced for 1 to 3 hrs/week (30.1%), followed by < 1 hour per week (19.1%).	Not reported.	Fair
63	Ten Velde, G., et al. (2021).	Cohort A: BAECKE questionnaire, Cohort B: BAECKE questionnaire and ActiGraph GT3X accelerometer; 1	Netherlands	Cohort A: 102 children, Cohort B: 131 children	Cohort A: 4-18, Cohort B: 7-12	During the COVID-19 pandemic, decreased PA was reported by 62% of children in cohort A and 54% of children in cohort B. In cohort A, school, sports, and leisure time PA significantly decreased ($p<0.01$) compared to before the COVID-19 pandemic, whereas in cohort B, only sports PA significantly decreased ($p<0.01$). In cohort B, light PA (LPA) and MVPA decreased from 252 ± 34 and 65 ± 18 min/d before the COVID-19 pandemic (May/June 2019) to 218 ± 39 and 48 ± 18 min/d during the COVID-19 pandemic (June 2020) (-34 ± 42 min/d, $p<0.01$; -17 ± 19 min/d, $p<0.01$). Similarly, while 64% of children in cohort B met PA recommendations (60 minutes of MVPA/day) before the COVID-19 pandemic, only 20% met recommendations during the COVID-19 pandemic ($p<0.01$). Total PA in cohort B was decreased by 51 ± 52 min/d compared to before the COVID-19 pandemic.	While girls had larger decreases in light PA (LPA) and MVPA than boys, only the difference in reduction of LPA between boys and girls was significant (−18 ± 38 vs −44 ± 41 min/day, $p=0.02$). Children with more MVPA min/d before the COVID-19 pandemic had larger reductions in MVPA compared to children with less MVPA before the COVID-19 pandemic.	Good
64	Theis, N., et al. (2021). "	IPAQ-SF; 2	UK	125 parents	8-16	The frequency of vigorous and light/moderate intensity PA decreased from 2 and 5 to 0 and 3 days/week from before to during the COVID-19 pandemic (median values;	Not reported.	Fair

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						z = −4.699, P < 0.001; median values; z = −3.979, P < 0.001). However, the duration of vigorous and light/moderate intensity PA did not significantly change with most children achieving < 30 minutes of vigorous intensity PA (z = −1.040, P = 0.073) and between 30 to 60 minutes of light/moderate intensity PA (z = −1.102, P = 0.070). (z = −1.040, P = 0.073). The MET values of vigorous and light/moderate intensity PA decreased by 48% (z = −4.334, P > 0.001) and 38% (z = −5.434, P > 0.001) from before to during the COVID-19 pandemic. Indoor play, cycling, walking, and at home PA classes reported as types of PA children engaged in during the COVID-19 pandemic.		
65	Tornaghi, M., et al. (2020).	IPAQ; 1	Italy	1568 children	15-18	Before the COVID-19 pandemic, 6.8% of children met PA recommendations (60 min of MVPA/day) compared to 14.7% during the COVID-19 pandemic. From before to during the COVID-19 pandemic, the percentage of children with a inactive (<700 MET-min/week) (17.8% vs 25.8%) or intense (>2520 MET-min/week) PA level increased (15.8% vs. 19.8%), while the percentage of children with a moderate (700-2519 MET-min/week) PA level decreased (66.3% to 53.6%).	Not reported.	Good
66	Wunsch, K., et al. (2021).	MoMo-PAQ; 1, 2	Germany	1711 children	4-17	Before the COVID-19 pandemic, male and female children (4-10) met PA recommendations (at least 60 minutes of PA) 4.74 and 4.62 days/week, while during the COVID-19 pandemic boys and girls met PA recommendations 5.39 and 5.27 days/week. Similarly, the days/week that male and female adolescents (11-17) met PA recommendations increased from 3.90 and 3.55 days/week to 4.08 and 3.96 days/week.	Sedentary time before the COVID-19 pandemic had a negative association with PA during the COVID-19 pandemic, independent of age and gender. In contrast, among females and children < 10 years, health related quality of life before the COVID-19 pandemic was positively associated with PA during the COVID-19 pandemic.	Good
67	Zorcec, T., et al. (2020).	Questionnaire; 2	Republic of Macedonia	72 parents/caregivers	7.3±2.89	Among children with cystic fibrosis (CF), asthma, tuberculosis (TB) and allergic rhinitis, the percentage of children who participated in more than 2 hours of PA/day significantly decreased from before to during the pandemic (52.8% and 20.8%, p=0.0001). 11.4% of children before the COVID-19 pandemic compared to 30.2% of children during the COVID-19 pandemic	Not reported.	Fair

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						participated in only a few hours of PA/week (p=0.0056).		
68	Carroll (2020)	IPAQ; 2	Canada	310 children, 254 families	18 months - 5 years	During lockdown, decreased PA was reported for 52% of children, with an average time spent outdoors and in active play of one hr/day. Parents reported decreased intensity of PA among children during the COVID-19 pandemic.	Parents reported PA was limited during the COVID-19 pandemic because of a lack of space and variety of tools/toys.	Good
69	Ellis, W. E., et al. (2020).	Godin Leisure-Time Exercise questionnaire ; 1	Canada	1054 children	14-18	Many participants reported no strenuous (40%) or moderate (21.3%) physical activity over the past week. During the COVID-19 pandemic, children participated in more than 15 minutes of mild PA 3.47 times, moderate PA 2.7 times, and strenuous PA 1.93 times.	Not reported.	Good
70	Guerrero, M. D., et al. (2020).	Online survey; 2	Canada	1472 parents	5-17	81.8% of children did not meet the PA recommendation.	Children were more likely to achieve PA recommendations if their parents were able to restrict screen time, had a higher income, or were younger than 43 years old. Furthermore, boys and children with increased outdoor PA and sport during the COVID-19 pandemic were more likely to achieve PA recommendations .	Good
71	Hemphill, N. M., et al. (2020).	Fitbit (step count)	Canada	109 children	9-16	Children with congenital heart disease obtained 21%-24% less daily steps during early-COVID. Daily steps were consistently below the Canadian PA guidelines of 60 minutes of MVPA/day (approximately equivalent to 12,000 steps/day).	Daily step counts were higher among boys than girls.	Good
72	McCormack, G. R., et al. (2020).	Online questionnaire ; 2	Canada	328 parents	5-17	During the COVID-19 pandemic, children met PA recommendations (≥60 min of MVPA) an average of 3.48 ± 2.41 days/week. Children played 4.52 ± 2.75 days in the past week and went to a park on 4.85 ± 6.39 days in the past month. Meanwhile, 18.3% of children reported 0 days of MVPA/week, 16.5% had 0 days of play per week, and 34.5% had no visits to a park in the past month. 48.8% of parents reported their child's PA at home increased and 32.9% of parents reported that their child's PA was the same compared to before the COVID-19 pandemic. 38.7% of parents reported their child's PA outdoors increased, while 39% of parents reported their child's PA outdoors decreased. 52.7% of parents reported their child's play at a park decreased, while 15.5% of parents reported their child's play at a park increased. 53.7% of	Children of parents with high COVID-19 anxiety had fewer days at the park and less PA both in the home (14.2% vs. 25.6%, $p < .05$) and outdoors (33.2% vs. 49.6%) compared to children of parents with low COVID-19 anxiety (3.00 days vs. 5.42, $p < .05$).	Fair

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						parents reported their child's play in public spaces decreased, while 9.5% of parents reported their child's play in public spaces increased.		
73	Mitra, R., et al. (2020).	Online survey; 2	Canada	1472 parents	5-17	More youth than children experienced a decrease in physical activity-related movements during the pandemic, including walking/biking, outdoor or indoor physical exercise and outdoor play. The majority of children reported a decrease in walking or biking (53.2%), PA or sport outside (63.8%), and outdoor play (51.2%) during the COVID-19 pandemic. In contrast, the majority of children reported PA or sport inside stayed the same (40.5%), while indoor play increased (53.1%).	Compared to children who reported decreased outdoor activity during the COVID-19 pandemic, a greater proportion of children who reported increased outdoor activity met PA guidelines (11.6% vs 26.5%, p<0.001) (60 minutes of MVPA/day). Younger children, children with a higher household income, children living in houses (vs apartments), living in multi-child households, and living further from major roads were more likely to cluster into the increased outdoor activity group. Gender was not associated with changes in outdoor activity. While neighborhood density was negatively associated with clustering into the increased outdoor activity group, access to a park within 1 km increased the likelihood of children living in high density neighborhoods clustering into the increased outdoor activity group (OR = 1.19).	Good
74	Moore, S. A., et al. (2020).	Online survey; 2	Canada	1472 parents	5-17	During the COVID-19 pandemic, 23.8% of children (5-13 years) and 13.2% of youth (14-17 years) met PA recommendations (60 minutes of MVPA/day). Children and youth attained 60 minutes of MVPA an average of 3.55 and 2.59 days/week, respectively. PA included activities such as walks or bikes in the neighborhood, PA or sport outside and inside, and outdoor play. Overall, children and youth had decreased PA and outside time during the COVID-19 pandemic, with the greatest reduction in outdoor PA and sport. In contrast, children and youth reported increased indoor play. Among outdoor activities, biking (6.1%), walking/hiking	A greater proportion of children (23.8%) met PA recommendations than youth (13.2%). More boys (5-11 years) met PA recommendations than girls (27.9% boys, 19.0% girls). Younger parental age, parental encouragement, parental co-participation in PA, parental cohabitation, living in a detached house (vs. apartment) and having a dog were positively associated with PA.	Good

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						(5.5%), and sports (3.5%) increased the most during the COVID-19 pandemic.		
75	Bazett-Jones (2020)	Online questionnaire ; 1	US	287 children	9-19	During COVID-19 restrictions, runners reported shorter distance runs ($p < 0.001$), fewer runs ($p < 0.001$), and fewer intense runs ($p < 0.001$) per week.	Not reported.	Fair
76	Dunton, G. F., et al. (2020).	Online survey; 2	US	211 children	5-13	During the COVID-19 pandemic, the most reported forms of PA were free play/unstructured activity (i.e. running around, tag) (90% of children) and walking (55% of children). Remote/streaming services were also used for PA programs (i.e. martial arts, dance, yoga classes) (28.9% of children), with older children (ages 9-13) five times more likely to participate in virtual team sports training sessions compared to younger children (ages 5-8)(OR = 5.40, 95% CI [1.70,17.15], Wald = 8.19, p = .004)Wald = .288, p = .633). Younger children (age 5–8) were more likely to participate in free play/unstructured physical activity, biking, and scootering/skateboarding/roller skating, while older children (ages 9–13) were more likely to participate in circuit training/conditioning. During the COVID-19 pandemic, the likelihood of participating in PA at home (OR = 2.49, 95% CI[1.35, 4.60], Wald = 8.593, p = .003 and in the neighborhood (i.e. on sidewalks and roads)(OR = 1.92, 95% CI [1.04,4.60], Wald = 4.28, p = .038) increased compared to before the COVID-19 pandemic. In contrast, the likelihood of participating in PA at parks and trails decreased (OR = 0.47, 95% CI [0.23, 0.97], Wald = 4.22, p = .040).	Parents perceived greater decreases in PA among older children (ages 9–13) compared to younger children (ages 5–8).	Good
77	Garcia, J. M., et al. (2020).	Online survey; 1	US	9 children	14-19	Prior to the pandemic, participants reported more days that they participated in 60 minutes or more of PA more frequently (4.17 days vs. 2.27 days; p = 0.0006) and participated in more activities (3.4 activities vs 2.11 activities; p = 0.007) than during the pandemic. 78% of the participants felt that their PA decreased.	The participants with decreased PA reported school PA program cancellations and fear of going outdoors as barriers to PA. The participant with increased PA reported it was because his family started riding bikes together.	Good
78	McGuine, T. A., et al. (2020).	Pediatric Functional Activity Brief Scale (PFABS); 1	US	13002 children	3-19	Among team sport athletes, lower levels of PA were reported compared to athletes involved in individual sports.	Lower levels of PA were reported among girls, athletes in the 12th grade, athletes who participated in team sports, and athletes from more	Good

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							impoverished areas.	
79	Pavlovic, A., et al. (2021).	Online questionnaire ; 3	US	2440; 1789 PE teachers, 64 district administrators, 62 school administrators, and 3 nurses	not specified (grades 3-12)	During the COVID-19 pandemic, 79% of participants reported students PA was “significantly less” or “somewhat less”. Frequently reported online PA resources included YouTube (29%),virtual learning platforms (27.9%), and PE teacher-led virtual classes (25.6%). Among schools that closed due to the COVID-19 pandemic, barriers to PA included student access to virtual learning and communication between teachers and students. Among schools that remained open, barriers to PA were social distancing guidelines and access to equipment and space for PA.	There were no significant differences in PA between children in different education levels (i.e., elementary, middle, or high schools) or regions of the U.S.	Good
80	Tulchin-Francis, K., et al. (2021).	Weighted Leisure-Time Score Index (unvalidated modified Godin Leisure-Time Exercise Questionnaire (mGodin); 2	US	1083 parents	3-18	While light PA was unchanged, MVPA of children significantly decreased during the COVID-19 pandemic (before: 46.7, during: 34.7, $p < 0.001$). For all ages, PA with friends, yard and neighborhood play (18.1%–39.8%, $p < 0.05$), and indoor child and parent-led play (6.8%–23.4%, $p < 0.05$) decreased. Preschool and elementary children reported decreased PA with family (8.3%–23.5%, $p < 0.05$) and a 7.1% to 20.1% increase in independent, virtual PA. Among preschool and elementary girls (20.3% and 5.7%, $p < 0.05$), as well as, elementary and middle school boys (5.1% and 13.8%, $p < 0.05$), increased yard play was reported. In contrast, there were no significant increases in outdoor PA among high school students. Before the COVID-19 pandemic, 78.6% of children participated in organized sports, while during the COVID-19 pandemic only 10.6% participated in organized sports.	The COVID-19 pandemic had the lowest impact on PA (based on quantity, variety, and intensity of PA) of preschool students and the highest impact on PA of high school students. Boys had higher reductions in PA than girls.	Good
81	de Matos (2020)	IPAQ; 1	Brazil	69 children	8-18	Weekly energy expenditure was significantly reduced among children (male: ES: 3.02, CI95%: [1.93; 4.12], $p<0.0001$; female: ES: 3.26, CI95%: [1.82; 4.69], $p<0.0001$) and adolescents (male: ES: 4.25, CI 95%: [3.06; 5.44], $p<0.0001$; female: ES: 4.01, CI 95%: [3.02; 5.00]; $p<0.0001$) during the COVID-19 pandemic.	Not reported.	Fair
82	Sa, C., et al. (2020).	Online survey; 2	Brazil	816 children	0-12	Most parents reported a decrease in PA during the COVID-19 pandemic, with children doing either much less PA (46.1% of parents) or less PA than during a normal school year (37% of parents). Children	Older children had lower levels of playing with PA than younger children. There were no significant relationships	Good

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						participated in 0.4±0.6 to 0.7±1.0 hours of PA/day during the COVID-19 pandemic.	between age and sex and organized or outdoor PA.	
83	Siegle, C. B. H., et al. (2020).	Online questionnaire ; 2	Brazil	816 children	0-12	During the COVID-19 pandemic, the highest average percentage of daily PA was 10.3±16.2% among boys ages 0 to 2, while the lowest average percentage of daily PA was 3.9±5.7 among girls ages 6 to 9. (%PA = playtime w/ PA + PA (planned, inside/outside the house, dog walking) / (playtime w/ PA + PA + playtime w/o PA + playtime on screens + intellectual (school)).	Percentage of PA (%PA) was higher among children with large external spaces at home than children with small external space (p=0.001) or with no external space (p<0.001). Older children had lower %PA than younger children. There was no significant effect of gender on differences in %PA.	Good
84	Aguilar-Farias (2020)	Online survey; 2	Chile	3157 children	1-5	For all age groups, the average duration of PA decreased by 0.75 hrs/day (−0.75 [CI 95% −0.81, −0.70] h/day).	Greater reductions in PA were reported for children with a more educated main caregiver or who lived in an apartment. Smaller reductions in PA were reported for children living with more children or with five or more people, children in rural areas, and children with space at home to play. While there was no effect of gender on PA, older children had less PA.	Good
85	Reece, L. J., et al. (2020).	Online survey; 2	Australia	16177 parents	4-18	During the COVID-19 pandemic, 31% of participants reported children's PA decreased a lot, while 39% reported children's PA decreased a little. For PA, 82% of children were active at home, while 52% of children were active in public spaces.	Not reported.	Fair
86	Cahal (2021)	Online questionnaire ; 2	Israel	445 children	0-18	PA decreased in 53.9% of patients with chronic respiratory disorders (i.e. asthma, recurrent pneumonia).	Older patients (>5 years old) had decreased PA compared to younger patients (p<.001).	Fair
87	Chaturvedi (2021)	Online survey; 1	India	303 children	7-17	Children spent an average of 0.82 hrs/day on fitness during the COVID-19 pandemic.	Not reported.	Good
88	Ghanamah, R. and H. Eghbaria-Ghanamah (2021).	Online survey; 2	Israel	382 parents	5-11	Children spent less time in physical activities during the COVID-19 pandemic than before. (before: 2.88 hours/day during: 2.02 hours/day, p<0.001)	Children spent less time in PA when a family member was diagnosed with COVID-19.	Good
89	Masi, A., et al. (2021).	Online survey; 2	Australia	302 caregivers	2-17	68% of caregivers for children with neurodevelopmental disabilities reported a decrease in exercise.	Not reported.	Fair
90	Munasinghe, S., et al. (2020).	PACE +, smartphone sensors (pedometer, MBAR); 1	Australia	582 children	13-19	PA decreased from before to during the COVID-19 pandemic (odds ratio [OR] = .53, 95% confidence interval [CI] = .34–.83), with a concurrent decrease in the average number of steps/day.	Not reported.	Fair

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91	Nathan, A., et al. (2021).	Online survey; 2	Australia	157 children	5-9	Compared to before the COVID-19 pandemic, the total minutes of PA/week did not significantly change during the COVID-19 pandemic. However, there was a 65.7% and 65% reduction in the duration and frequency of organized PA (-124.6 min/week, p<0.001; -1.3 times/week, p<0.001). In contrast, the duration and frequency of total (23.1% or 146.3 min/week, p=0.005 and 30% or 1.8 times/week, p<0.001) and home-based (58.7% or 201 min/week, p<0.001) unstructured PA increased. Other activities that significantly increased from before to during the COVID-19 pandemic included outdoor play (i.e., in the yard or street around the house, in a park or outdoor recreation area) and home indoor play. There was a 95% increase in the min/week reported for outdoor play in a park, playground, or outdoor recreation area.	Parents reported facilitators of PA during the COVID-19 pandemic as increased time at home to support PA, more children outside playing together, more utilization of local PA resources (i.e., parks), more unstructured PA, and more parental encouragement.	Good
92	Parker, K., et al. (2021).	Online survey; 1	Australia	963 children	13-17	During the COVID-19 pandemic, 7.2% of children met PA recommendations (60 min of MVPA/day). Among the 26.5% of children who used digital platforms for PA, streaming services were used by 40.0%, online classes were used by 30.2%, and subscriber fitness programs were used by 13.7% of those children. The median frequency and duration of digital platform use for PA were 4 (IQR 3-7) times per week and 120 (IQR 60-260) min/week.	Children who used digital platforms for PA during the COVID-19 pandemic were over 2 times more likely to meet PA recommendations .	Good
93	Sciberras, E., et al. (2020).	Online survey; 2	Australia	213 children	5-17	Among kids with ADHD, there was decreased exercise (Odds Ratio (OR) = 0.4; 95% CI 0.3–0.6) and outdoor time (OR = 0.4; 95% 0.3–0.6) compared to pre-COVID.	Not reported.	Good
94	Zhao, Y., et al. (2020).	Online questionnaire ; 1, 2	China	738 students, 1062 parents	11.0±1.7	During the COVID-19 pandemic, 26% of children reported 0 hours, 18% reported <1 hour, 37.9% reported 1-2 hours, and 18% reported more than 2 hours of daily outdoor activity. In contrast, 43.7% of parents reported their child's daily outdoor activity was 0 hours. 42.9% of children in grades 7-9 reported 0 hours of daily outdoor activity compared to 24.1% of children in grades 1-3 and 23.8% of children in grades 4-6.	Not reported.	Fair
96	Wu, X., et al. (2021).	Telephone questionnaire ; 2	China	43 children	0-18	Among children with type 1 diabetes, 44.1% reported PA decreased during the COVID-19 pandemic. Before the COVID-19 pandemic, outdoor activities (i.e., cycling, basketball) were predominant forms of exercise. However, during the COVID-19 pandemic, the predominant form of exercise was indoor	Not reported.	Fair

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						activities (i.e., pacing, skipping rope).		
97	Zhang, X., et al. (2020).	IPAQ-SF; 1	China	9979 children	9-14	Students obtained an average of 23.19 minutes of moderate-to-vigorous PA (MVPA)/ day (1193.02 ± 1621.88 MET-min/week). Vigorous PA made up 42.74% (510.40 ± 934.18 MET-min/week) of total PA, while walking for PA made up 24.19% (288.60 ± 613.08 MET-min/week).	Girls participated in significantly more MVPA and moderate PA than boys during the COVID-19 pandemic (p<0.01). Similarly, younger children in grade 4 participated in significantly less MVPA and moderate PA than older children in grades 5 and 6. (p<0.01)	Good
98	Abid (2021)	Ricci and Gagnon sedentary behavior questionnaire ; 1	Tunisia	100 children	5-12	Compared to before the COVID-19 pandemic, sports and recreational PA decreased by 35%, daily PA decreased by 16% for boys and 27% for girls, and total PA decreased by 7% for boys and 17% for girls during the COVID-19 pandemic (p < 0.001).	There was no significant effect of gender on PA.	Fair
99	Shinomiya, Y., et al. (2021).	Online survey; 2	Japan	2019: 2017 children, 2020: 295 children	18-30 months	The percentage of leisure time that consisted of outdoor play decreased from an average of 64.0 ± 26.0% before the COVID-19 pandemic (March 2019) to 61.0 ± 27.1% during the COVID-19 pandemic (March 2020) (p = 0.058).	Children who stayed at home had less outdoor play than children who received childcare at a nursery school (p=0.019).	Good
100	Xiang, M., et al. (2020).	Global Physical Activity questionnaire (GPAQ); 1	China	2426 children	6-17	Before the COVID-19 pandemic, PA decreased from a median of 540 min/week to 105 min/week during the COVID-19 pandemic (-435 min/week, p<0.001). The percentage of children who met PA recommendations (at least 60 min of PA/day) decreased from 60% to 17.7% during the COVID-19 pandemic (-42.3%).	Not reported.	Fair
101	Yang, S., et al. (2020).	IPAQ-long form; 1	China	2824 children	17.5 ± 1.2	High school students reported their MVPA (80.4%), active transport for commuting and errands (77.4%), housework activity (50.1%), and walking for leisure (79.9%) stayed the same. The hrs/week that high school students participated in MVPA remained unchanged at an average of 1.5 hrs/week.	Not reported.	Fair
102	Elnaggar, R. K., et al. (2020).	PAQ-A; 1	Saudi Arabia	63 children	14-18	From baseline to follow-up, the PA level (PAL) of all participants was significantly reduced (BL-PAL: 3.05 ± 0.54; FL-PAL: 2.77 ± 0.47; P < .001).	While PAL decreased for both genders, only the PAL reduction was significant in boys (BL-PAL: 3.20 ± 0.57; FU-PAL: 2.76 ± 0.49; P < .001). At baseline, boys achieved significantly higher PAL than girls (P = .014), but at follow-up both genders had similar PAL (P = .86).	Fair
103	Jia, P., et al. (2021).	IPAQ-long form; 1	China	2824 children	16-18	Compared to before the COVID-19 pandemic, the frequency of active transport (i.e., commuting and errands) among high school students decreased	Not reported.	Good

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											from 1.3 to 0.9 days/week (p<0.001), while leisure-time walking decreased from 1.0 to 0.7 days/week (p < 0.001) during the COVID-19 pandemic. Similarly, the frequency of moderate-to-vigorous housework decreased from 2.3 to 1.9 days/week (p < 0.05) and leisure-time moderate-to-vigorous PA decreased from 0.7 to 0.65 days/week (p < 0.001).

[a] 1 = child reported measure; 2 = parent reported measure, 3 = other secondary subjective reported measure

Abbreviations: PA, physical activity; NIH NHLBI, National Institute of Health National Heart, Lung, and Blood Institute; CI, confidence interval; h/day, hrs/day; MVPA, moderate-to-vigorous physical activity; M, mean; SD, standard deviation; PAL, physical activity level; ES, effect size; min/d, min/day; OR, odds ratio; Wald, Wald test; BL, baseline; FU, follow up; P.E., physical education; min/wk, min/week; ml.kg−1.min−1, millimeters per kilogram per minute; h/d, hrs/day; km, kilometers; ADHD, attention-deficit/hyperactivity disorder; LPA, light physical activity; MET, metabolic equivalent task

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1 **Table 2**. Characteristics of the Physical Activity Data for the Included Articles (N=69).

	Total Articles	Articles
PA Data Reported by:		
Child	28	39-42, 44, 49, 53, 57, 59-63, 65, 69, 75, 77, 78, 81, 87, 90, 92, 97, 98, 100-103
Parent	32	35, 36, 38, 43, 45, 48, 50-52, 54-56, 64, 67, 68, 70, 72-74, 76, 80, 82-86, 88, 89, 91, 93, 96, 99
Child and Parent	5	37, 46, 58, 66, 94
Other (Fitbit, accelerometer, VO2, smartphone sensor)	7	34, 38, 47, 49, 63, 71, 90
Teacher and Parent	1	59
Teacher and School Administrator	1	79
PA Measure		
IPAQ (short or long form)	8	60, 65, 66, 69, 82, 98, 102, 104
PAQ-A	5	40-43, 103
PAQ-C	2	45, 46
PACE+	2	53, 90
Godin Leisure-Time Exercise Questionnaire (or modified version)	2	69, 80
Other online survey	39	35-37, 43, 48-52, 54, 56, 58, 61-63, 70, 72-79, 82-89, 91-94, 98-100
MoMo-PAQ	2	60, 66
Telephone interview	4	38, 55, 57, 96
In-person questionnaire	2	44, 67
Accelerometer (GENEActiv tri-axial, ActiGraph GT3X)	4	35, 39, 50, 64
FitBit	1	71
Smartphone sensors (pedometer, MBAR)	1	90
VO2 max (20 meter shuttle run test)	1	47
Physical Activity Time Frame		
During the COVID-19 pandemic	13	36, 46, 56, 58, 62, 69, 70, 78, 83, 87, 92, 94, 97
Compared PA before to during the COVID-19 pandemic	56	34, 35, 37-45, 47-55, 57, 59-61, 63-68, 71-77, 79-82, 84-86, 88-91, 93, 96, 98-103
Did PA increase or decrease?		
PA decreased	50	34, 35, 37, 39-45, 47-55, 57, 59, 61, 63-65, 67, 68, 71, 73-77, 79-82, 84-86, 88-90, 93, 96, 98-103
PA increased	4	38, 60, 66, 72
PA stayed the same	2	91, 101
FITT Principle reported		
Frequency	30	39, 40, 44-46, 50, 52, 53, 60, 61, 64-66, 69, 70, 72, 74, 75, 77, 78, 80-82, 85, 91-93, 97, 103
Intensity	25	35, 38, 47, 50, 54, 55, 61, 64-66, 69, 70, 73-76, 81, 82, 86, 93, 98, 99, 101, 102, 104
Time	46	34, 37, 43, 46, 48, 49, 51, 53-69, 72-74, 76, 77, 81-85, 87, 88, 90-94, 97-101
Type	30	38, 40, 41, 45-47, 53, 61, 62, 64, 65, 70, 73-75, 77, 79-81, 86, 91-94, 97-100, 102, 104

Abbreviations: PA, physical activity; IPAQ, International Physical Activity Questionnaire; PAQ-A, Physical Activity Questionnaire for Adolescents; PAQ-C, Physical Activity Questionnaire for Children; PACE+, Patient-centered Assessment and Counseling for Exercise plus Nutrition; MoMo-PAQ, Motorik-Modul Physical Activity Questionnaire

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