Impact of COVID-19 pandemic lockdown on movement behaviours of children and adolescents: a systematic review

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ABSTRACT
Introduction Several studies have examined how the lockdown restrictions enforced to halt the spread of COVID-19 have affected children and adolescents’ movement behaviours, but there is a need to synthesise these findings. Therefore, we conducted this systematic review to examine the impact of COVID-19 lockdown on children and adolescents’ movement behaviours.

Methods We searched eight databases and grey literature for relevant studies of all study designs; and conducted a narrative analysis of the results following synthesis without meta-analysis guidelines. We used appropriate tools to assess the risk of bias in quantitative and qualitative studies. We compared changes in physical activity, screen time and sleep duration and quality from before to during the COVID-19 lockdown.

Results This review included 71 studies reporting data from 35 countries and territories, mostly from high-income economies. A majority of the studies used a cross-sectional design and had fair to poor-quality ratings. Most studies reported reduced physical activity, increased screen time and longer sleep hours among children and adolescents. Children and adolescents facing strict lockdowns saw a larger decline in physical activity and a sharper increase in screen time than those under mild restrictions.

Conclusion COVID-19-related lockdowns were detrimental to children and adolescents’ movement behaviours, with stricter lockdowns tending to have a bigger impact. Children and adolescents under COVID-19 restrictions are likely to be less active, spend more time on screen, and sleep longer hours than before the lockdown. More studies from low-income and middle-income countries could provide a clearer picture of the impact.

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INTRODUCTION
COVID-19, one of the biggest pandemics in the history of humankind, has affected almost every country worldwide. The COVID-19 outbreak that started in Wuhan, China, in December 2019 has caused 317.26 million infections and 5.52 million deaths globally as of 13 January 2022. WHO declared a Public Health Emergency of International Concern on 30 January 2020 to accelerate action against the rapidly spreading coronavirus. Following the WHO recommendations, governments in many countries started to enforce lockdown measures to curb the spread of the virus. During these lockdowns, schools, businesses and other non-essential services were closed, and people were advised to stay inside their homes.
behaviours—physical activity, sedentary behaviour and this active age can negatively affect their movement of their time inside their residence. Such confinement for leisure activities.10 Children’s sleep patterns might such as mobile phones, tablets, computers and television physical activity under normal circumstances.8 School closure means children cannot participate in physical education classes, which are a significant contributor to children’s total physical activity under normal circumstances.8 School closure also affects active commute to and from the school.9 Additionally, having limited opportunities to go outdoors during the lockdown would significantly reduce children’s outdoor play. Confined children with more free time might turn to screen-based electronic devices such as mobile phones, tablets, computers and television for leisure activities.10 Children’s sleep patterns might become irregular as they do not have to attend regular classes.11 12 Their sleep quality might decrease during the lockdown because of the fear and anxiety caused by the pandemic.13–15 Unhealthy movement behaviours are associated with adverse health outcomes such as obesity, hypertension, diabetes, cardiovascular diseases, poor mental health and lower health-related quality of life.16–18

Several individual studies have been conducted in various countries to see the impact of COVID-19-related lockdown restrictions on children and adolescents’ movement behaviours. However, the results reported by these studies vary in both the degree and the direction of effect.3 11 20 Moreover, the degree of lockdown restrictions varies between and within countries and can affect children and adolescents’ movement behaviours differently. Stockwell and colleagues conducted a systematic review to examine changes in physical activity and sedentary behaviour from before to during COVID-19 lockdown among the general population.20 However, this review included few studies on children and adolescents as it included studies until October 2020. A systematic review and meta-analysis was conducted to assess the prevalence and pattern of sleep disturbances in children and adolescents during the COVID-19 pandemic. However, this review searched articles only in three databases, and therefore, included few studies.22 A narrative review of the literature was done to understand health-related behaviours among isolated preschool and school-aged children aged 3–12.23 This narrative review included articles from a limited number of databases, focused on children in social isolation and social deprivation, and excluded children with previous health conditions or diseases. Similarly, Paterson et al conducted a scoping review to explore the impact of COVID-19 on the movement behaviours of children and youth aged 5–17 years. However, this review did not appraise the quality of the evidence, included some articles without peer review, and did not account for the varying degrees of lockdown restrictions.24 Moreover, many studies have been published on this topic since these reviews were undertaken. Therefore, we conducted this systematic review to comprehensively review the findings from studies conducted in different settings and varying degrees of lockdown restrictions to inform policy decisions on enforcement of lockdowns for subsequent waves of COVID-19 and future pandemics of similar nature.

METHODS

We registered the review protocol in PROSPERO (registration number: CRD42021245924, see online supplemental file 1) and followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and synthesis without meta-analysis (SWiM) guidelines.25

Inclusion criteria

We defined the population, exposure, comparators, outcomes and studies for this review as follows:

Population: Children and adolescents (aged 19 years and below)

Exposure: COVID-19 pandemic lockdown

We took the reference of an earlier study26 and used the information provided in each article to categorise the severity of lockdown into the following five categories.

1. Mild lockdown: schools open, advised to maintain social distance.
2. Moderate lockdown: schools closed or available to children of essential workers, advised to stay indoors and maintain social distance while being outdoors.
3. Strict lockdown: schools closed, mandatory home confinement except for essential reasons, ban on public gatherings, closure of organised sports and recreation facilities, public parks open, allowed to go outdoors at least for a certain time.
4. Very strict lockdown: schools closed, non-essential businesses closed, closure of organised sports and recreation facilities, closure of public parks, not allowed to go outdoors even for exercise.
5. Unclear: no sufficient information on lockdown available.

Comparators: Outcomes before the COVID-19 lockdown versus outcomes during the COVID-19 lockdown.
Outcomes: Movement behaviours—physical activity, sedentary behaviours and sleep.37

To be more specific, physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure.36 It can take different forms such as walking, cycling, sports, active recreation and play, and household chores.28 29 Based on intensity, physical activity can be categorised into light, moderate and vigorous.36

Sedentary behaviour is any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents, while in sitting, reclining or lying posture.31 Sedentary behaviours include sitting and using screens, such as watching television and using smartphones and computers for playing videogames and accessing the internet and social media.31 In this review, sedentary behaviour included use of screens.

Sleep duration is the period between bedtime and wake-up time.32 Sleep quality refers to how well one sleeps, and can be determined by various components, such as sleep duration, sleep disturbance, sleep latency and sleep efficiency.33 34

Types of studies: We included original research articles with all types of study designs, such as randomised controlled trial (RCT), quasi-experimental, cohort, observational, cross-sectional and other comparative studies, as well as case studies and evaluation reports. We excluded letters, editorials, reviews, conference abstracts and books.

Search strategy
We searched eight electronic databases: PubMed/MEDLINE, Web of Science, Cumulative Index of Nursing and Allied Health Literature (CINAHL), PsycINFO, PsycARTICLES, Academic Search Complete, SociINDEX, and Cochrane Central Register of Controlled Trials (CENTRAL); and grey literature: World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), European Centre for Disease Prevention and Control (ECDC), Japan International Cooperation Agency (JICA) and United Nations Children’s Fund (UNICEF). Additional studies were hand-searched from the reference lists of included articles. We conducted the search at three time points, initially on 30 March 2021, the first update on 24 September 2021 and the final update on 10 December 2021. We included all published papers in the English language from 1 November 2019 to 10 December 2021.

Our search strategy combined both Medical Subject Headings (MeSH) terms and free-text terms related to children/adolescents AND lockdown AND movement and play behaviours (see online supplemental file 2).

Data extraction
Authors RRC and JLS independently searched the aforementioned electronic databases using the search strategy outlined in the review protocol. The titles and abstracts of all the articles retrieved from the search were screened by the two researchers independently, and duplicates were removed. The full texts of the potential articles to be included in the study were then reviewed by two researchers (MK and SU) independently based on the inclusion criteria. Any discrepancies between the two researchers were resolved through discussion with a third researcher (RRC).

We extracted data from the selected studies using an excel sheet, and included the following information: author, year and country; study title; source; study design; study setting; study population; sample size; mean age; proportion of female; measurement tools for physical activity, sedentary behaviour and sleep; description of lockdown; comparison; outcomes and remarks.

Risk of bias and quality of evidence
All the studies finally included in this review were observational. We used the ‘Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies’ of the US Department of Health and Human Services, National Institutes of Health to assess the risk of bias for cohort and cross-sectional studies.35 For qualitative studies, we used the ‘Qualitative study: Critical Appraisal Skills Programme’.36 None of the included studies used RCTs or mixed-methods design. We used an approach reported by Geere et al to rate the strength of evidence from observational cohort and cross-sectional studies, considering study quality, number of evidence and consistency of findings.37

Analysis strategy
We did not perform a meta-analysis due to the heterogeneity of designs and measures in the included studies. Therefore, we conducted a narrative analysis of the results following the SWiM guidelines (see online supplemental file 3).36 We categorised studies according to the three outcomes—physical activity, sedentary behaviour (screen time) and sleep (duration and quality), and described changes in relevant indicators from before to during the COVID-19 lockdown (see figure 1). Studies under each outcome were presented based on the direction (ie, increased, decreased, no significant change from before to during the lockdown) and the effect size of their results. When necessary, we standardised the unit of outcome measurements reported among included studies to compare the results easily.

RESULTS
Figure 2 shows the PRISMA flow diagram. Initially, we retrieved 14 241 records from the database search and identified an additional 16 articles from other sources. After removing the duplicates and screening the titles and abstracts of the articles, the full texts of 150 potential articles were assessed. Finally, we included 71 articles after removing ineligible articles (see online supplemental table 1).

Studies included in this review came from a range of countries and territories—11 studies reported data from...
Italians; 9 from the USA; 7 each from Spain and Turkey; 6 from Australia; 5 each from Canada and China; 4 each from the UK, Poland and India; 3 each from France and Portugal; 2 each from Germany, the Netherlands, Switzerland, Brazil, Chile, Hong Kong (China) and Malaysia; and 1 each from Croatia, Ireland, Russia, Sweden, Ukraine, Bangladesh, Indonesia, Israel, Pakistan, Singapore, Sri Lanka, Uzbekistan, Vietnam, Colombia, Egypt and Morocco. Of the 71 studies included in this review, 67 were single-country studies—the majority (51) from high-income economies, 13 from upper-middle-income economies and 3 from lower-middle-income economies; and 4 were multicountry studies reporting data from high-income, upper-middle-income and lower-middle-income economies. However, one of the multicountry studies did not specify the countries, instead reported that data were collected mostly from North America, the Middle East, Europe and South America. There were no studies from low-income countries. Twenty-three and 48 studies were published in 2020 and 2021, respectively.

Characteristics of studies included in this review are presented in Table 1. All the studies were observational, and the majority were quantitative studies. Of the 71 studies, 20 were cohort (data were collected at two time points, for before lockdown and during the lockdown; prospective=18 and retrospective=2), 48 were cross-sectional (data were collected at the same time, for during lockdown and retrospectively for before the lockdown or repeated cross-sectional), and 3 were qualitative in design. The sample size (range: 9–29 202) and participants’ age (range: 1–19 years) among the included studies varied widely. A majority of the studies (69%) reported strict lockdown, while 9.8% reported moderate lockdown, 8.5% reported very strict lockdown, 4.2% reported mild lockdown and 8.5% did not provide sufficient information on lockdown.

The risk of bias assessment for the included quantitative studies is presented in online supplemental table 2. Almost all the studies clearly stated their research objectives, defined their study population and recruited the study population following the inclusion and exclusion criteria. However, most studies (86.8%) did not justify the sample size as they used a convenience sampling strategy. None of the studies measured exposure prior to the outcome because most of them used a cross-sectional study design. More than 86% of the studies did not have significant issues in measuring exposure and outcome. Only 36.8% of the studies had adjusted for potential confounders. The quality appraisal of qualitative studies is presented in online supplemental table 3. All the three studies did not have any major issues in their design and implementation.

### Movement behaviours among apparently healthy children and adolescents

#### Physical activity

Changes in physical activity from before to during the lockdown are presented in Table 2. Thirty-four studies (11 cohort, 21 cross-sectional and 2 qualitative) reported changes in physical activity among apparently healthy children and adolescents from before to during the lockdown. Of these, 25 studies (8 cohort and 16 cross-sectional and 1 qualitative) observed a decline in physical activity, 8 (2 cohort, 5 cross-sectional and 1 qualitative) observed no change and 1 (cohort) reported an increase in physical activity.

The decline in physical activity among children and adolescents during the lockdown ranged from 102.5 min per week in a study in Spain to 91 min per day in another study from the same country. In Brazil, 83% of the adolescents spent less or much less time on physical activity during the pandemic than before the pandemic, and the proportion of physically active children reduced from 59.1% to 7.0% during the same period. Reductions in physical activity levels were also observed among children and adolescents in Chile, Singapore, the UK, Croatia, Australia (New South Wales), Canada, Poland, the USA, China, France, Portugal, Italy and Turkey. In contrast, in some countries, children and adolescents could maintain or even increase their physical activity levels despite the pandemic restrictions. For example, studies from Italy, China, Australia (Western Australia) and Poland observed no significant change in physical activity levels from before to during the lockdown among children and adolescents. A multicountry longitudinal study also reported no significant change in time spent on total physical activity among children aged 3–5 years old. German children and adolescents were found...
to be more active during the COVID-19 lockdown, as the number of days active in a week and the proportion adhering to physical activity guidelines increased during this period (4.3 days/week to 4.7 days/week, p<0.01; and 19.1% to 30.2%, p<0.01; respectively).

Sedentary behaviour

% Exposure to screen

Changes in screen time from before to during the lockdown are presented in table 3. Thirty-one studies (8 cohort, 21 cross-sectional and 2 qualitative) compared children and adolescents' screen time before and during the lockdown. All of them observed an increase in screen time during the pandemic compared with before the pandemic. During the lockdown, the increase in children’s screen time ranged from 55 min per day in a multi-country study to 2.9 hours per day in Spain. Another study from Spain found that children’s screen time increased by 1.8 hours per day, reaching an alarming figure of 6.1 hours per day during the lockdown. Singaporean and German children spent daily 1.54 hours and 1.02 hours more, respectively, on screen during the pandemic than before the pandemic. In Italy, 9 out of 10 Italian children spent more time on screen during the lockdown than before the lockdown and the proportion of children and adolescents using smartphone for four or more hours per day increased from 16.3% before the lockdown to 66.3% during the lockdown. In Brazil, nearly three-fourths of the children reported spending more or much more time on screen during the lockdown than before the pandemic. Similar findings were reported in studies from Canada, China, Turkey and Portugal. Approximately two-thirds of the children and adolescents in France and India spent more time on screen during the lockdown than before the lockdown.

Sleep

Sleep duration, bedtime and wake-up time

Changes in sleep duration, bedtime and wake-up time from before to during the lockdown are presented in table 4. Twenty-five studies (9 cohort and 16 cross-sectional) reported changes in sleep duration among children and adolescents from before to during the pandemic. Twelve studies (five cohort and seven cross-sectional) reported an increase, two
| Study                        | Study design      | Study population                              | Sample size | Mean age (SD) | Female (%) | Description of lockdown                                                                 | Classification of lockdown | Outcomes of interest assessed                  |
|-----------------------------|-------------------|-----------------------------------------------|-------------|---------------|------------|----------------------------------------------------------------------------------------|-----------------------------|-----------------------------------------------|
| Adibelli and Sümen, 2020, Turkey | Cross-sectional   | Children aged 7–13 years                      | 597         | 9.87 (1.99)   | 55.8%      | Implemented lockdown, suspended formal education and practised distance education        | Strict lockdown             | Sleep quality                                 |
| Aguilar-Farias et al, 2020, Chile | Cross-sectional   | Children aged 1–5 years                       | 3157        | 3.10 (1.38)   | 49.4%      | All schools closed, work-from-home strategies, all national parks closed, lockdowns and curfews in some districts | Strict lockdown             | Physical activity, screen time, sleep duration, sleep quality |
| Alonso-Martínez et al, 2021, Spain | Cohort (Prospective) | Preschoolers aged 4–6 years from schools      | 21          | Not reported  | 42.9%      | Mandatory home lockdown; closure of non-essential businesses and schools                  | Strict lockdown             | Physical activity                              |
| AMHSI, 2020, Multicountry    | Cohort (Prospective) | Healthy volunteers with stay at home for 14 days or more aged 15–18 (subgroup) | 3078        | Not reported  | 43.5%      | Stay-at-home for 14 days or more                                                        | Strict lockdown             | Sleep duration                                 |
| Araby et al, 2021, Egypt     | Cross-sectional   | School children aged 6–14 years               | 1507        | Not reported  | 40.9%      | Total lockdown measures                                                                  | Strict lockdown             | Sleep quality                                 |
| Bingham et al, 2021, UK      | Cohort (Prospective) | Children aged 9–13 years                      | 643         | 9.10 (1.10)   | 49.4%      | Extreme restrictions on movement, people not allowed to leave their residence except for reasonable excuses such as buying food and medical supplies, people could also go out for a short exercise (60 min) daily, all playgrounds and indoor and outdoor play facilities closed, schools closed for most children except for vulnerable children and children of key workers | Strict lockdown             | Physical activity                              |
| Bronikowska et al, 2021, Poland | Cohort (Prospective) | Adolescent Polish youths                      | 127         | 15.40 (0.50)  | 52.0%      | From 1 to 20 April, children below 18 years were not allowed to leave their home without their guardians, later they could go out maintaining 2 m distance and covering their mouth and nose, sports facilities were closed until 4 May | Strict lockdown             | Physical activity                              |
| Study                          | Study design            | Study population                     | Sample size | Mean age | Female (%) | Description of lockdown                                                                 | Classification of lockdown | Outcomes of interest assessed                  |
|-------------------------------|-------------------------|--------------------------------------|-------------|----------|------------|------------------------------------------------------------------------------------------|------------------------------|-----------------------------------------------|
| Brzek et al, 2021, Poland     | Cohort (Prospective)    | Children aged 3–5 years              | 1316        |          | 55.6%      | School closure, ban on public gatherings,                                                | Strict lockdown              | Physical activity, screen time, sleep duration |
| Cacioppo et al, 2020, France  | Cross-sectional        | Children with physical disabilities aged 0–18 years | 1000 | 9.50 years (4.80) | 46.0% | Lockdown in France from 17 March 2020 to 11 May 2020                                      | Unclear                      | Physical activity, sleep quality               |
| Çakıroğlu et al, 2021, Turkey | Cross-sectional (Repeated) | Children and adolescents aged 10–18 years | Before: 581 During: 410 |          |          | Temporary closure of all educational institutions, sports centres, cultural venues, and entertainment centres; curfew imposed for children below 20 years as of 4 April 2020; work from home policies enacted by many private and public institutions, including schools | Very strict lockdown          | Screen time (digital gaming)                  |
| Cardy et al, 2021, Canada     | Cross-sectional        | Canadian children with autism spectrum disorder (ASD) aged 19 years and younger | ASD: 127 ASD: 11.70 years (4.06) ASD: 78.0% |          |          | School closure, prolonged exposure to the pandemic response (2- to 3-months)             | Unclear                      | Screen time                                   |
| Carrillo-Diaz et al, 2021, Spain | Cross-sectional (for physical activity and media use) | Adolescents aged 11–17 years who attended appointments at private clinics (dental wear) | 213 | 14.00 years (1.90) | 54.5% | Obligatory total lockdown from 16 March to 4 May                                           | Strict lockdown              | Physical activity, media use                  |
| Censi et al, 2021, Italy      | Cross-sectional        | Italian children aged 2–11 years      | 1027        |          | 46.0%      | Rigorous isolation measures and confinement at home enforced by the Italian government through the decree from the second week of March 2020 until 18 May | Strict lockdown              | Physical activity, screen time                |
| Cellini et al, 2021, Italy    | Cross-sectional        | Children 6–10 years                   | 299         | 7.96 years (1.36) | 46.5% | National lockdown; all schools and nonessential businesses closed; people not allowed to leave their homes unless for an essential reason, remote work | Strict lockdown              | Sleep duration, bedtime, rise time, sleep quality |
| Study                          | Study design     | Study population                                         | Sample size | Mean age              | Female (%) | Description of lockdown                                                                 | Classification of lockdown | Outcomes of interest assessed                  |
|-------------------------------|------------------|----------------------------------------------------------|-------------|-----------------------|------------|------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------|
| Cerasuolo et al, 2021, Italy   | Cross-sectional  | Italian toddlers (0–3 years) and preschoolers (4–5 years) | 112 (Toddlers = 61, Preschoolers = 51) | 3.09 years (1.88) | 41.7%       | Nationwide lockdown with severe control measures such as home confinement, movement restrictions, smart remote working, and temporary closure of non-essential businesses and schools; people allowed to leave their residence only for demonstrated necessities, such as health issues, basic needs and work | Strict lockdown                 | Bedtime, rise time, sleep quality              |
| Chaffee et al, 2021, USA      | Cohort (Prospective) | Students in grades 9 or 10                               | Baseline: 1423 Follow-up: 1006 | Not reported       | Follow up: 62.0%           | Statewide stay-at-home order in California declared on March 19, 2020                  | Strict lockdown                 | Physical activity                             |
| Chakraborty et al, 2021, India | Cross-sectional  | Children and adolescents aged 3–15 years                 | 645         | 8.30 years (3.50)     | 48.4%       | Nationwide lockdown from 25 March 2020, initially for 21 days and extended many times with some relaxations; during the lockdown, all schools, shopping malls, local markets, workplaces and public transports completely shut down except for emergency services such as hospitals, petrol pumps, groceries, etc. | Strict lockdown                 | Screen time (Media use)                       |
| Chambonniere et al, 2021, France | Cross-sectional  | French children and adolescents aged 6–17 years          | 6491        | Not reported          | 57.6%       | National lockdown from 14 March 2020, for 55 days, complete closure of all primary and secondary schools shifting all the teaching activities to virtual mode | Strict lockdown                 | Physical activity, screen time                |

Table 1 Continued
| Study                          | Study design | Study population                                                                 | Sample size | Mean age | Female (%) | Description of lockdown                                                                 | Classification of lockdown | Outcomes of interest assessed                                      |
|-------------------------------|--------------|----------------------------------------------------------------------------------|-------------|----------|------------|------------------------------------------------------------------------------------------|---------------------------|---------------------------------------------------------------------|
| Cheng et al, 2021, Malaysia    | Cross-sectional | Children and adolescents with type 1 (T1DM) and type 2 diabetes mellitus (T2DM) aged less than 18 years | 123 (T1DM = 93, T2DM = 30) | T1DM: 11.08 years (3.47) T2DM: 13.81 years (2.03) | Total: 56.1% T1DM: 52.7% T2DM: 66.7% | 18 March 2020 to 3 May 2020: Total nationwide lockdown (known as Movement Control Order) forcing the closure of schools and all non-essential businesses and restricting outdoor sports, leisure activities, and travel between states and districts; followed by partial lockdown with the gradual lifting of restrictions in phases (4 May to 9 June: Conditional Movement Control Order and 10 June 2020 to 31 March 2021: Recovery Movement Control); travel restriction and schools closure remained throughout | Strict lockdown | Physical activity, screen time, sleep duration |
| Clarke et al, 2021, UK         | Qualitative  | Preschool aged children (3–5 years)                                              | 20 parents | Not reported | 16 mothers, 4 fathers | ‘Stay at home’ order allowing people to leave the house only to buy essential supplies, attend medical appointments, or exercise once a day; schools and nurseries closed except for vulnerable or ‘keyworker’ children; non-essential businesses closed | Strict lockdown | Physical activity, screen time, sleep quality |
| DiGiorgio et al, 2020, Italy   | Cross-sectional | Children aged 2–5 years                                                          | 245         | 4.00 years | 43.7%      | National lockdown; temporary closure of schools and non-essential businesses, movement restriction, work from home | Strict lockdown | Bedtime, wake time, sleep quality |
| Di Giorgio et al, 2021, Italy  | Cross-sectional | Children with Fragile X-Syndrome, aged 2–16 years                                | 53          | 9.71 years (4.14) | 15.1%      | Total lockdown: home confinement, movement restriction, smart remote work and temporary closure of non-essential businesses and schools | Strict lockdown | Physical activity, sleep duration, sleep quality |

Table 1 Continued
| Study | Study design | Study population | Sample size | Mean age | Female (%) | Description of lockdown | Classification of lockdown | Outcomes of interest assessed |
|-------|--------------|------------------|-------------|----------|------------|-------------------------|---------------------------|------------------------------|
| Dondi et al, 2021, Italy | Cross-sectional | Children aged ≤18 years, including children with disabilities, ASD, chronic diseases and specific learning disabilities | 6210 | Not reported | Not reported | Total lockdown from 11 March 2020 to 18 May 2020, during the first wave of COVID-19 pandemic | Strict lockdown | Sleep quality |
| Esentürk, 2020, Turkey | Qualitative | Children with ASD aged 9–16 years | 10 | 12.10 years | 50.0% | Reduction of public transport, closure of all schools, cancellation of arts and sports events, mandatory quarantine for the people who traveled from abroad, closure of public places such as cafes/cinemas/the mall, curfews for the citizens over 65, under 20 and those with chronic illnesses | Very strict lockdown | Physical activity |
| Eyler et al, 2021, USA | Qualitative | Parents of children aged 5–12 years | In 16 interviews, 16 parents reported on 23 children | Not reported | 56.5% (Children) | COVID-19 stay-at-home orders | Strict lockdown | Physical activity, screen time |
| Eyler et al, 2021, USA | Cross-sectional | Children aged 5–12 years | 245 | 8.10 years | 48.6% | Compulsory stay-at-home orders issued by 42 states and territories from 1 March 2020 to 31 May 2020; school closure; physical education and after-school sports programmes halted or limited to virtual options; other extracurricular, community-based opportunities for physical activity halted; outdoor spaces such as parks and playgrounds also closed | Strict lockdown | Physical activity |
| Garcia et al, 2021, USA | Cohort (Prospective) | Adolescents with ASD aged 14–19 years | 9 | 16.87 years (1.36) | 11.1% | Most people in the US forced to remain in quarantine for several weeks to months, resulting in a complete disruption of daily routines for most school-aged children and adolescents | Strict lockdown | Physical activity, screen time, sleep duration |

Table 1 Continued
| Study                                      | Study design | Study population                                      | Sample size | Mean age       | Female (%) | Description of lockdown                                                                 | Classification of lockdown | Outcomes of interest assessed                      |
|--------------------------------------------|--------------|-------------------------------------------------------|-------------|----------------|------------|-----------------------------------------------------------------------------------------|----------------------------|---------------------------------------------------|
| Guo et al, 2021, China                     | Cross-sectional | Chinese students in primary, secondary and high schools | 10,461      | Not reported   | 49.9%      | Home confinement, school closures, social distance measures, restriction on group activities, team sports or playgrounds, home confinement | Strict lockdown             | Physical activity, screen time, sleep duration     |
| Kaditis et al, 2021, Multi-country         | Cross-sectional | Children aged less than 18 years                      | 845         | Not reported   | 45.8%      | Governments and local authorities urged their citizens to remain at home, implementation of strict social distancing rules, closure of enterprises and schools | Strict lockdown             | Bedtime, wake time, sleep duration                 |
| Kahn and Gradisar, 2021, USA               | Cohort (Prospective) | Infants 6–18 months old                               | 610         | 2019: 11.8 months (3.5) 2020: 11.9 months (3.7) | 2019: 51.5% 2020: 49.8% | Governments urged their citizens to remain at home, implementation of strict social distancing rules, closure of enterprises and schools | Strict lockdown             | Nighttime sleep duration, morning rise time       |
| Kolota and Glabska, 2021, Poland           | Cross-sectional | Adolescents aged 10–16 years                         | 1334        | Not reported   | 53.3%      | Primary schools closed, and lessons shifted to online mode since 12 March 2020 and was continuing at the time of the survey (June 2020), during that period, people were advised to limit personal contact and not leave their homes until necessary, wearing a face mask in public places made mandatory on 16 April 2020 | Strict lockdown             | Physical activity, screen time                     |
| Lavigne-Cerván et al, 2021, Spain         | Cross-sectional | Children and adolescents aged from 6–18 years         | 1028        | 10.34 years (3.64) | 46.6%      | State of alarm declared; educational institutions and many workplaces closed; entire population forced to stay indoors | Strict lockdown             | Sleep quality                                     |
| Li et al, 2021, China                      | Cohort (Perspective) | Teenagers aged 14–19 years                            | 1020        | 15.87 years (0.74) | 58.9%      | Social isolation policy, people forced to remain homebound, national school closures and study online for nearly three months | Strict lockdown             | Sleep duration, sleep quality                     |

Continued
| Study                  | Study design      | Study population                      | Sample size | Mean age       | Female (%) | Description of lockdown                                                                 | Classification of lockdown | Outcomes of interest assessed |
|-----------------------|-------------------|---------------------------------------|-------------|----------------|------------|------------------------------------------------------------------------------------------|-----------------------------|-------------------------------|
| Lin et al, 2020, Singapore | Cross-sectional  | Children aged between 3 and 16 years | 593         | Median: 8.00 years, IQR: 6.00–11.00 | Not reported | National lockdown (called ‘Circuit Breaker’): closure of all non-essential services and workplaces, including schools, stores, and recreational facilities; online learning | Strict lockdown              | Physical activity, screen time, sleep duration, bedtime, wake time, sleep quality |
| Liu et al, 2020, China | Cross-sectional (Repeated) | Preschoolers aged 4–6 years | Before COVID-19: 1619 During COVID-19: 436 | Before COVID-19: 5.03 years During COVID-19: 5.01 years | Before COVID-19: 49.5% During COVID-19: 51.1% | Nationwide school closure; all citizens, including children required to stay indoors | Strict lockdown              | Sleep duration, bedtime, wake time, sleep quality |
| Lokhandwala et al, 2021, USA | Cohort (Perspective) | Children aged 36–70 months | 16 | 56.4 months (10.8) | 18.8% | Shutdown of schools and non-essential businesses as part of the state of Massachusetts’s stay-at-home advisory | Strict lockdown | Sleep duration, wake-up time |
| López-Bueno et al, 2020, Spain | Cross-sectional | Children and adolescents aged 3–16 years | 860 | 9.60 years (3.90) | 49.2% | Strict confinement (minors not allowed to go out except for medical reasons, those aged 15 and over could go out once a day for shopping or taking a dog for a short walk, maintaining a social distance of 1.5 m) | Very strict lockdown | Physical activity, screen time, sleep duration |
| Luijten et al, 2021, Netherlands | Cross-sectional (Repeated) | Dutch children and adolescents aged 8–18 years | Before lockdown: 2401 During lockdown: 844 | Before lockdown: 13.10 (3.14) During lockdown: 13.40 (2.80) | Before lockdown: 49.7% During lockdown: 52.6% | 12 March 2020—people asked to stay inside and work from home as much as possible and to follow social distancing (1.5 m), all large events canceled; partial lockdown implemented on March 15—closure of all schools and child care facilities (except for children of essential care workers), as well as sports and leisure facilities, bars, and restaurants; children still allowed to play outside; May 11—primary schools partially reopened, and on June 2 secondary schools followed | Strict lockdown | Sleep quality |
| Study                      | Study design     | Study population                                                                 | Sample size | Mean age | Female (%) | Description of lockdown                                                                 | Classification of lockdown | Outcomes of interest assessed                |
|---------------------------|------------------|----------------------------------------------------------------------------------|-------------|----------|------------|-----------------------------------------------------------------------------------------|----------------------------|---------------------------------------------|
| Łuszczki et al, 2021, Poland⁹¹ | Cross-sectional (Repeated) | Polish children and adolescents aged 6–15 years                                 | 1016        | Before: 10.51 years (2.13) During: 10.79 years (2.02) | Before lockdown: 50.3% During lockdown: 51.9% | March 10–12: cancellation of mass events and closure of all educational institutions and offices; measures further tightened on 25 March, limiting religious gatherings and forbidding non-essential travel | Strict lockdown | Physical activity, media use, sleep duration and quality |
| Masi et al, 2021, Australia⁹² | Cross-sectional | Children with neurodevelopmental disability aged 2 to 17 years                 | 302         | 9.70 years | 33.1%      | At the time of the study, state governments had started easing restrictions, with further easing imminent in most states | Mild lockdown | Physical activity, media use, sleep quality |
| Medrano et al, 2021, Spain⁹³ | Cohort (Prospective) | Schoolers aged 8 to 16 years                                                    | Before lockdown: 291 During lockdown: 113 | Before lockdown: 12.10 years (2.90) During lockdown: 12.00 years (2.60) | Before lockdown: 47.8% During lockdown: 48.7% | One of the strictest alarm state, schools closed, mandatory home confinement for children | Strict lockdown | Physical activity, screen time, sleep duration |
| Minuto et al, 2021, Italy⁹⁴ | Cohort (Retrospective) | Young T1D patients aged 6–39 years (outcomes available for sub-groups)         | Total: 202 6–18 years: 107 | Total: 18.30 years (6.43) | Total: 47.0% | Started with the first emergency measures such as suspension of schools, sports activities, and meetings, followed by a national quarantine from March 9, 2020, restricting movement except for necessity | Strict lockdown | Physical activity |
| Mitra et al, 2020, Canada⁹⁵ | Cross-sectional | Children and youth aged 5–17 years                                               | 1472        | Children: 8.12 years (2.04) Youth: 14.85 years (1.68) | 47.0% | Physical distancing rules (two or more meters), social gatherings prohibited, team sports canceled, playgrounds and parks closed, most public schools closed | Strict lockdown | Physical activity, screen time, sleep duration, sleep quality |
| Monteiro et al, 2021, Portugal⁹⁶ | Cross-sectional | Children aged 6 months to 6 years and 12 months                                 | 193         | 42.9 months (20.6) | 44.0% | Schools closed and shifted to online learning; outings limited to essential activities such as buying food, going to the pharmacy, and running and bike riding for a short distance when alone; children allowed to play outdoor for short periods | Strict lockdown | Screen time |

Table 1 Continued
Table 1 Continued

| Study                          | Study design      | Study population                          | Sample size | Mean age | Female (%) | Description of lockdown                                                                                                                                                                                                 | Classification of lockdown | Outcomes of interest assessed |
|-------------------------------|-------------------|-------------------------------------------|-------------|----------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------------------|
| Moore et al, 2020, Canada     | Cross-sectional   | Children and youth aged 5-17 years        | 1472        | Children: 8.12 years (2.04) Youth: 14.85 years (1.68) | 47.0%       | Physical distancing rules (two or more meters); limited community and social gatherings, sport, and playground and park use; most schools closed, and classroom lessons replaced by homeschooling and online learning | Moderate lockdown            | Physical activity, screen time, sleep duration, sleep quality |
| Morgü et al, 2020, UK         | Cross-sectional   | Children aged 5 to 11 years               | 927         | 7.45 years (2.04) | 45.5%       | Lockdown started on 23rd March, 2020; nationwide school closure except for children of key workers                                                                                                                      | Moderate lockdown            | Physical activity, screen time, sleep duration |
| Munasinghe et al, 2020, Australia | Cohort (Prospective) | Young people aged 13-19 years | 582         | Median: 17.00 years (Interquartile range: 16.00-18.00) | 79.9%       | Physical distancing policies implemented, people requested to stay at their homes wherever possible and limit their travel to obtain essential goods and services; school closures | Mild lockdown               | Physical activity, screen time, sleep duration |
| Nathan et al, 2021, Australia | Cross-sectional   | Children aged 5 to 9 years from Western Australia | 157         | 6.90 years (1.70) | 45.9%       | State of emergency declared; indoor sporting facilities and playgrounds closed; people told to stay at home except for buying food and necessities, seeking medical care, work, study, and exercise complying with public gathering requirements | Mild lockdown               | Physical activity, screen time, sleep duration |
| Ng et al, 2020, Ireland       | Cross-sectional   | Irish adolescents aged 12-18 years         | 1214        | Not reported        | 72.0%       | Social distancing rules, closure of schools, online schooling from home, club training canceled, going outdoors not allowed apart from one walk a day                                                                 | Strict lockdown            | Physical activity              |
| Oflu et al, 2021, Turkey      | Cross-sectional   | Healthy children aged 3–10 years applying to the pediatrics clinics for outpatient care | 253         | 6.30 years (1.40) | 47.0%       | Schools and nurseries closed; curfew implemented for those under the age of 20                                                                                                                                          | Very strict lockdown        | Screen time                     |
| Study | Study design | Study population | Sample size | Mean age | Female (%) | Description of lockdown | Classification of lockdown | Outcomes of interest assessed |
|-------|--------------|------------------|-------------|----------|------------|------------------------|---------------------------|-----------------------------|
| Okely et al., 2021, Multi-country[26] | Cohort (Prospective) | Children aged 3 and 4 years | 948 | Before COVID-19: 4.40 years (0.60) During COVID-19: 5.20 years (0.60) | 49.0% | 41% of the participants faced high (Early Childhood Education and Care (ECEC) services closed, people not allowed to go out in public to exercise), 46% moderate (ECECs closed, advised to limit time outside), and 13% low levels of restrictions (pre-schools open or available to children of essential workers, allowed to go out in public for exercise). | Strict lockdown | Physical activity, screen time, sleep duration and quality |
| Ozturk Eyimaya and Yalçin Irmak, 2021, Turkey[58] | Cross-sectional | Children studying in grades 1-8, aged 6-13 years | 1115 | 9.03 years (1.95) | 53.4% | All schools closed and shifted to remote education, temporary lockdown on children and young people under the age of 20 | Very strict lockdown | Screen time |
| Pietrobelli et al., 2020, Italy[34] | Cohort (Prospective) | Children and adolescents with obesity aged 6-18 years | 41 | 13.00 years (3.10) | 46.3% | Three weeks’ national lockdown, mandatory home confinement | Strict lockdown | Physical activity, screen time, sleep duration |
| Pombo et al., 2021, Portugal[62] | Cross-sectional | Children aged 13 years | 2159 | Not reported | 48.3% | March 16: Nationwide closure of schools, companies, and non-essential public services; March 18: state of emergency declared – movement restrictions on the entire population, all non-essential businesses closed except supermarkets, pharmacies, and gas stations, and only take-aways allowed from restaurants | Strict lockdown | Physical activity, screen time |
Table 1  Continued

| Study                        | Study design | Study population                                      | Sample size | Mean age | Female (%) | Description of lockdown                                                                 | Classification of lockdown | Outcomes of interest assessed |
|------------------------------|--------------|-------------------------------------------------------|-------------|----------|------------|-----------------------------------------------------------------------------------------|------------------------------|-------------------------------|
| Ramos Socarras et al.        | Cross-sectional | Adolescents and young adults aged 12 to 25 years (outcomes available for sub-groups) | Total 498 (12-14 years: 108, 15-17 years: 141) | Total sample: 18.17 years (3.72) | 76.3% (12-14 years: 74.6%, 15-17 years: 79.8%) | March 13, 2020: state of emergency and the lockdown declared with severe restrictions in the first month, including the closure of schools, public places (casinos, gyms, bars, public pools, arenas, ski centres, theaters, etc), and non-essential businesses such as restaurants, daycare, shopping centres, hair salon, and prohibition of gatherings and travel between different regions; restrictions made more flexible from the beginning of May 2020 | Strict lockdown | Sleep duration, sleep quality |
| Ruiz-Roso et al.              | Cross-sectional | Adolescents aged 10 years to 19 years and 11 months | 726 | Not reported | 59.6% | Lockdown in Italy, Spain, Colombia, and Brazil; no national lockdown in Chile, but mandatory quarantine in some communities | Strict lockdown | Physical activity |
| Sá et al. 2021, Brazil        | Cross-sectional | Children aged less than 13 years | 816 | Not reported | 49.4% | Social isolation, face-to-face school activity fully suspended, long period of movement restriction without any organised physical activity or possibility to play outdoors | Strict lockdown | Physical activity, screen time, sleep duration |
| Saxena et al. 2021, India     | Cohort (Prospective) | School children aged 9-14 years | 1237 | Baseline: 11.88 years (1.01) | 40.9% | School closure | Unclear | Screen time |
| Schmidt et al. 2020, Germany  | Cohort (Prospective) | 4-to 17-year-olds | 1711 | Before lockdown: 10.36 years (4.04) During lockdown: 11.34 years (4.06) | 49.8% | Schools, sports clubs, gyms, and recreational facilities closed; physical distancing measures implemented; playing outdoors allowed if done alone or with family members | Moderate lockdown | Physical activity, screen time |
| Sciberras et al. 2020, Australia | Cross-sectional | Children with ADHD aged 5-17 years | 213 | 10.59 years (3.10) | 23.6% | Citizens required to stay at home except for essential reasons | Moderate lockdown | Physical activity, screen time |

Continued
| Study                          | Study design | Study population                        | Sample size | Mean age            | Female (%) | Description of lockdown                                                                                                                                                                                                 | Classification of lockdown | Outcomes of interest assessed |
|-------------------------------|--------------|-----------------------------------------|-------------|---------------------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------|
| Serra, 2021, Italy [57]       | Cohort (Perspective) | Italian children and adolescents aged 6 to 18 years | 184         | 14.84 years (2.73)  | 71.7%      | During the second wave of the pandemic, the country divided into red, orange, and yellow zones based on the scenario of epidemiological risk; in areas with increased risk of COVID-19 spread, people’s movement and economic and social activities more limited; intermittent school lessons in physical presence for children of infant schools, primary schools and some lower secondary schools and only online lessons for other lower secondary school children and high school adolescents | Moderate lockdown          | Screen time                 |
| ten Velde et al, 2021, Netherlands [64] | Cohort (Retrospective) | Cohort A: children aged 4 to 18 years Cohort B: primary school children (7-12 years) | Cohort A: 102 Cohort B: 131 | 10.50 years (3.60) 56.5% | 10.20 years (0.90) 56.5% | Nationwide shutdown of schools, sports clubs, bars, and restaurants                                                                                                                                                     | Strict lockdown            | Physical activity, screen time |
| Tornaghi et al, 2020, Italy [65] | Cross-sectional | Italian youngsters aged 15-18 years from North-western Lombardy high schools | 1259 (Before and during lockdown) | Not reported | 76.9% | Initially limited and then suspended nonessential movement, except activities practised within a 200 m home-block area maintaining a distance of at least 1 m                                                                 | Strict lockdown            | Physical activity            |
| Tso et al, 2020, Hong Kong [109] | Cross-sectional | Children aged 2-12 years                 | 29202       | 6.50 years (2.84) 48.6% |            | All schools closed                                                                                                                                                                                                      | Unclear                    | Screen time                 |
| Tulchin-Francis et al, 2021, USA [59] | Cross-sectional | Children aged 3 to 18 years               | 1310        | Not reported | 51.3% | government-mandated activity restriction, including social distancing and stay-at-home orders                                                                                                                                 | Strict lockdown            | Physical activity            |
| Türkoglu et al, 2020, Turkey [66] | Cross-sectional | Children and adolescents aged 4-17 years diagnosed with ASD | 46          | 7.89 years 17.4%  |            | Schools closed, individuals <20 under home confinement                                                                                                                                                                  | Very strict lockdown       | Sleep quality               |
| Study | Study design | Study population | Sample size | Mean age | Female (%) | Description of lockdown | Classification of lockdown | Outcomes of interest assessed |
|-------|--------------|------------------|-------------|----------|------------|--------------------------|----------------------------|-----------------------------|
| Werling et al, 2021, Switzerland³⁷ | Cross-sectional | Patients referred for attention deficit hyperactivity disorder aged 10 to 18 years | 126 | Not reported | 25.4% | March 16, 2020: complete lockdown resulting in school closure and homeschooling; first easing of restrictions starting from April 26 with first schools reopened on May 11 and most students returned to classes in June 2020, at least part-time | Moderate lockdown | Screen time |
| Werling et al, 2021, Switzerland³⁸ | Cross-sectional | Children and adolescents with psychiatric disorders aged 10 to 18 years | 477 | 13.96 years (2.29) | 41.9% | March 16, 2020: complete lockdown resulting in school closure and homeschooling; schools gradually reopened after May 11, 2020, but many students did not return to onsite class before the second week of June, often with reduced onsite hours, and in some cases, not at all before the summer vacation | Moderate lockdown | Screen time |
| Yang et al, 2020, China³⁶ | Cross-sectional | High school students (sub-group) | 2824 (High school students) | 17.50 years (1.20) | 76.0% | COVID-19 lockdown from 24 January to 23 February | Unclear | Physical activity, screen time, sleep duration |
| Zenic et al, 2020, Croatia³⁹ | Cohort (Prospective) | Adolescents attending high school | 823 | 16.50 years (2.10) | Not reported | Schools closed; extensive social distancing measures implemented, including a ban on public gatherings and closure of nonessential services such as restaurants, shopping centres, sports and recreational facilities, and places of worship | Strict lockdown | Physical activity |
| Zengin et al, 2021, Turkey⁴¹ | Cross-sectional | Children aged 9 to 12 years attending primary schools | 309 | 10.30 years (1.20) | 47.9% | Complete closure of schools (distance learning) and a partial or full-time curfew for children under the age of 20 | Very strict lockdown | Physical activity, sleep duration and quality |

ADHD, Attention deficit hyperactivity disorder; ASD, Autism spectrum disorder.
Table 2  Changes in PA from before to during the lockdown

| Study                                    | Measurement tool                                      | Indicator                                                                 | Before lockdown (mean (SD)) | During lockdown (mean (SD)) | During lockdown (vs before lockdown) | P value |
|------------------------------------------|------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------|------------------------------|-------------------------------------|---------|
| Aguilar-Farias et al, 2020, Chile³⁹       | Adapted from the questions included in the International Study of Movement Behaviours in the Early Years (SUNRISE), pilot-tested | Mean time spent on PA (hours/day)                                         | 3.60 (1.97)                 | 2.82 (2.15)                  |                                     | <0.001  |
| Alonso-Martínez et al, 2021, Spain⁴⁰    | Wrist-worn GENEActiv tri-axial accelerometer         | Total PA (minutes/day)                                                   | 346.9 (54.6)                | 303.6 (76.5)                |                                     | 0.002   |
| Bingham et al, 2021, UK⁴¹                | Before lockdown: Physical activity questionnaire for children (PAQ-C) During lockdown: Modified version of the Youth Activity Profile (YAP) | % Being sufficiently active                                               | 69.4%                       | 28.7%                       |                                     | <0.001  |
| Bronikowska et al, 2021, Poland⁴²       | Physical Activity Screening Measure                   | Group not meeting the WHO’s MVPA recommendations before lockdown          |                             |                             |                                     | 86.6%   | 0.04   |
|                                          |                                                      | % Maintaining the same insufficient level of PA during lockdown           |                             |                             |                                     |         |
|                                          |                                                      | Group meeting the WHO’s MVPA recommendations before lockdown             |                             |                             |                                     | 50.0%   | 0.01   |
|                                          |                                                      | % Significantly decreasing their level of MVPA below the recommendations during lockdown |                             |                             |                                     |         |
| Brzek et al, 2021, Poland⁴³             | Questionnaire related to PA, and it changes during the COVID-19 restrictions | % Physically active                                                      | 81.1%                       | 67.2%                       |                                     | <0.001  |
| Cacioppo et al, 2020, France⁴⁵          | Questionnaire developed by a national multidisciplinary group experienced in disability care, pilot-tested | % WHO practised PA during lockdown                                       |                             |                             |                                     | 56.0%   |
| Carrillo-Diaz et al, 2021, Spain⁴⁶     | Physical Activity Questionnaire (IPAQ-SF)            | Physical activity (total minutes of leisure METs per week)               | 856.6 (343.5)               | 332.8 (91.6)                |                                     | <0.01   |
### Table 2  Continued

| Study                          | Measurement tool                                                                 | Indicator                                                                 | Before lockdown (mean (SD)) | During lockdown (mean (SD)) | During lockdown (vs before lockdown) | P value |
|-------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------|------------------------------|-------------------------------------|---------|
| Censi et al, 2021, Italy⁴⁴    | Eating Behaviours Physical Activity and Lifestyle-COVID-19 (EBPAL-COVID-19) questionnaire | % Who stopped their habitual PA during lockdown                           |                             | 78.1%                        | <0.001                             |         |
| Chaffee et al, 2021, USA⁴⁵    | PA assessed by asking 'How many days (0–7) in the past 7 days, did you exercise or were physically active for at least 20 min that made you sweat or breathe hard?' | % Being physically active for five or more days in the past week           |                             |                              | 0.82                               |         |
|                              |                                                                                  | 6 month follow-up before lockdown (baseline vs 6 month follow-up)          | From 53.7% to 52.9%         |                              |                                    |         |
|                              |                                                                                  | 6 month follow-up during lockdown (baseline vs 6 month follow-up)          | From 54.0% to 38.1%         |                              | <0.001                             |         |
| Chambonniere et al, 2021, France⁴⁶ | Questionnaires developed based on the IPAQ and ONAPS-Q questionnaires in adults and Youth Risk Behaviour Surveillance System (YRBSS) investigation in children and adolescents | % Reporting decreased PA from before to during lockdown                   |                             | 42.0%                        | 58.7%                              |         |
| Cheng et al, 2021, Malaysia⁴⁸ | Physical Activity Questionnaire for Children (PAQ-C) and the Physical Activity Questionnaire for Older Children (PAQ-A) adapted from Crocker et al and Kowalski et al | Physical Activity Questionnaire Score (range: 1–5, higher score indicates a higher level of PA) |                             | Type 1 Diabetes, Male          | 2.08 (0.70)                        | <0.001  |
|                              |                                                                                  |                                                                           |                             | Type 1 Diabetes, Female       | 2.00 (0.38)                        | <0.001  |
|                              |                                                                                  |                                                                           |                             | Type 2 Diabetes, Male         | 1.91 (0.56)                        | 0.066   |
|                              |                                                                                  |                                                                           |                             | Type 2 Diabetes, Female       | 1.79 (0.41)                        | 0.063   |
| Clarke et al, 2021, UK⁴⁷      | Topic guide for in-depth interviews to get insights into the perceived impact of lockdown restrictions on preschool children's PA, sedentary behaviour, food intake, and sleep | Children's PA                                                            |                             | Most parents reported a reduction |                                     |         |
| Study                          | Measurement tool                                                                 | Indicator                                                                 | Before lockdown (mean (SD)) | During lockdown (mean (SD)) | During lockdown (vs before lockdown) | P value |
|-------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------|-----------------------------|-------------------------------------|---------|
| Di Giorgio et al, 2021, Italy | PA assessed by the question ‘is your child involved in sports activities?’      | % Involved in sport activities                                            | 66.0%                      | 11.0%                       |                                     | <0.001  |
| Esentürk, 2020, Turkey        | Interview form prepared based on relevant literature and validated through opinions from experts | Barriers to PA                                                            |                            |                             | Parents reported barriers for PA    |         |
| Eyler et al, 2021, USA        | Questions from an existing scale of child PA practices (HomeSTEAD's PA and screen media practices and beliefs survey) | % Reporting decreased PA from before to during lockdown                   |                            |                             |                                     | 63.7%   |
| Eyler et al, 2021, USA        | Interview guide to assess parents’ perceptions of their child’s PA and screen time during COVID-19 stay-at-home orders (pilot-tested) | Parents’ perception about change in their children’s PA from before to during lockdown |                            |                             | Remained the same or increased     |         |
| Garcia et al, 2021, USA       | Adapted from the National Survey of Children’s Health                           | Days per week of 60+ min of PA                                            | 4.17 (1.52)                | 2.27 (2.22)                 |                                     | <0.001  |
| Guo et al, 2021, China        | Change in PA assessed with the question, ‘Compare with the 3 months before the outbreak of COVID-19, is there any difference in the time you (or your child) spend on daily physical activity?’ | % Reporting decreased PA from before to during lockdown                   |                            |                             |                                     | 58.7%   |

Continued
| Study                                | Measurement tool                                                                 | Indicator                                                                 | Before lockdown (mean (SD)) | During lockdown (mean (SD)) | During lockdown (vs before lockdown) P value |
|-------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------|-----------------------------|---------------------------------------------|
| Kołota and Głabska, 2021, Poland    | Short-Form Survey Instruments for Children’s Diet, Physical Activity and Sedentary Behaviour | % Physically active for ≥3 days/week                                      | 59.4%                      | 62.4%                       | 0.112                                       |
| Lim et al, 2020, Singapore          | Questionnaire which included information on physical exercise                   | Time spent on physical exercise (hours/day)                              | 1.13 (0.60)                | 0.91 (0.73)                 |                                             |
| López-Bueno et al, 2020, Spain      | PA assessed with the question, ‘How many minutes of physical activity does your child usually perform weekly?’ | PA (minutes/week)                                                        | 198.6 (180.9)              | 96.1 (123.0)                | <0.001                                       |
| Łuszczki et al, 2021, Poland        | PA assessed with the question, ‘Over the last week, how many days have you performed 60 min or more of PA that increased your breathing rate?’ | Days with 60 min or longer PA                                             | 3.89 (1.89)                | 3.30 (2.07)                 | <0.001                                       |
| Masi et al, 2021, Australia         | Questionnaire developed by the investigators and pilot tested with clinicians, researchers, and a small group of parents | % Reporting decrease in children’s exercise                               |                             |                             | 68.0%                                       |
| Medrano et al, 2021, Spain          | ‘The Youth Activity Profile’ questionnaire (YAP)                                 | PA (minutes/day)                                                         | 150.0 (40.0)               | 63.0 (39.0)                 | <0.001                                       |
| Minuto et al, 2021, Italy           | Not reported                                                                     | Sports (hours/week)                                                      | Age ≥6 years <10 years     | 4.36 (0.94)                 | 0.14 (0.38)                                 |
|                                     |                                                                                 |                                                                           | Age ≥10 years <14 years    | 6.01 (4.06)                 | 1.82 (2.32)                                 |
|                                     |                                                                                 |                                                                           | Age ≥14 years <18 years    | 5.14 (4.20)                 | 2.72 (3.40)                                 |

Table 2 Continued
| Study                        | Measurement tool                                                                 | Indicator                                                                 | Before lockdown (mean (SD)) | During lockdown (mean (SD)) | During lockdown (vs before lockdown) P value | P value |
|-----------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------|-----------------------------|---------------------------------------------|---------|
| Mitra et al, 2020, Canada   | Secondary data (parents reported time spent on various movement behaviours)       | % With decreased outdoor activities during lockdown compared with before the lockdown |                            | 56.0%                       |                                             |         |
| Moore et al, 2020, Canada   | Secondary data (change in child's movement and play behaviours), test–retest (1 week) reliability assessed | Change in PA or sport outside from before to during lockdown (range: 1–5, 3=no change) |                            | 2.28 (1.22) Youth: 1.96 (1.13) Children: 2.28 |                                             |         |
| Morgü et al, 2020, UK       | Family daily routines and children's emotional and behavioural symptoms questionnaire developed by Orgilés et al | % Engaging in at least 60 min of PA per day                               | 67.3%                      | 51.1%                       |                                             |         |
| Munasinghe et al, 2020, Australia | PACE+Adolescent Physical Activity Measures (baseline) Ecological momentary assessment (EMA) (follow-up) | Physically active for≥60 min per day (OR)                                | 1.00                       | 0.53 (0.34, 0.83)           |                                             |         |
| Nathan et al, 2021, Australia | Questionnaire adapted from the Healthy Active Preschool Years Study              | Total PA (minutes/week)                                                  | 809.7 (584.4)              | 835.4 (642.4)               | 0.647                                       |         |
| Ng et al, 2020, Ireland     | PACE+instrument (validated against accelerometers)                              | % Having less PA during lockdown compared with before the lockdown         |                            | 49.7%                       |                                             |         |
| Okely et al, 2021, Multi-country | Questionnaire developed by the researchers based on the recommendations for each behaviour guideline, tested and refined as part of SUNRISE pilot study | Time spent in total PA (minutes/day)                                      | 200.7 (5.0)                | 217.8 (4.8)                 | 25.1(−31.7, 81.9)* 0.361*                   |         |

Table 2 Continued
| Study                          | Measurement tool                                                                 | Indicator                                                                 | Before lockdown (mean (SD)) | During lockdown (mean (SD)) | During lockdown (vs before lockdown) | P value |
|-------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------|----------------------------|-------------------------------------|---------|
| Pietrobelli et al, 2020, Italy | Questionnaire which included questions on sports activity participation (during lockdown any PA was considered as sports) | Sports (hours/week)                                                      | 3.60 (4.25)                 | 1.29 (1.44)                 |                                     | 0.003   |
| Pombo et al, 2021, Portugal    | Questionnaire developed by the researchers, questions validated by child development experts, and pilot tested | % Spending less time (less and much less) on PA during lockdown compared with before the lockdown | 72.3%                       |                            |                                     |         |
| Ruiz-Roso et al, 2020, Multi-country | International Physical Activity Questionnaire (IPAQ)                  | % Physically active                                                        | 27.0%                       | 20.5%                      |                                     |         |
| Sá et al, 2021, Brazil        | Questionnaire created by the research team, elaborated by experts in the field and tested | % Spending less or much less time on PA                                   | 83.0%                       |                            |                                     |         |
| Schmidt et al, 2020, Germany  | The MoMo PA questionnaire                                                        | PA guideline adherence (%)                                                | 19.1%                       | 30.2%                      | <0.01                               |         |
| Sciberras et al, 2020, Australia | CoRonavRuS Health Impact Survey                                       | Regular exercise (OR)                                                     | 1.00                        | 0.40 (0.30, 0.60)          |                                     |         |
| ten Velde et al, 2021, Netherlands | Cohort A: BAECKE questionnaire (validated)                               | Total PA (score, range 1–15)                                             | Cohort A: 9.29 (1.03)       | Cohort A: 8.94 (1.07)       | Cohort A:<0.01                       |         |
|                               | Cohort B: BAECKE questionnaire (validated)                                   | Light PA (minutes/day)                                                   | Cohort B: 9.03 (1.22)       | Cohort B: 8.89 (1.30)       | Cohort B: 0.16                      |         |
|                               | Cohort B: Accelerometer (n=64)                                               | Moderate-to-vigorous PA (minutes/day)                                    | 252.0 (34.0)                | 218.0 (39.0)                | <0.01                               |         |
|                               | IPAQ (Italian language)                                                      | PA level (MET-minutes/week)                                              | No significant change       |                            |                                     |         |
| Tornaghi et al, 2020, Italy   | IPAQ (Italian language)                                                      | PA level (MET-minutes/week)                                              | No significant change       |                            |                                     |         |
reported a decrease, and eleven (four cohort and seven cross-sectional) reported no significant change in sleep duration. The increase in daily sleep duration among children and adolescents ranged from 11 min in Chile and the USA to approximately 1 hour in a multicountry study. Spanish children slept approximately 48 min more on weekdays and approximately 42 min more on weekends during the COVID-19 confinement. Similar results were observed among preschoolers in China. Italian and Singaporean children slept approximately 27 min and 20 min more, respectively, during the lockdown than before the lockdown. Studies from the UK and Poland reported that children slept less during the lockdown than before the lockdown. Two multicountry studies and studies from Spain, Australia, the USA, Portugal and China did not observe any significant difference in sleep duration among children and adolescents from before to during the lockdown.

Ten studies compared bedtime and wake-up time and one more study compared wake-up time before and during the lockdown. All of them reported that children and adolescents went to bed later and woke up later during the COVID-19 lockdown than before the lockdown, except three studies, of which one reported no change in wake-up time and two reported no change in wake-up time on weekend days from before to during the lockdown. In Italy, children’s bedtime and wake-up time shifted by 53 min and 66 min, respectively. A similar shift in bedtime and wake-up time was observed among Singaporean children. A multicountry longitudinal study among children aged 3–5 years observed that children went to bed 34 min later and woke up 59 min later.

Sleep quality
Changes in sleep quality from before to during the lockdown are presented in table 4. Nineteen studies (4 cohort, 14 cross-sectional and 1 qualitative) reported changes in sleep quality from before to during the COVID-19 lockdown. Eight (one cohort, six cross-sectional and one qualitative) of them observed a decrease, five (one cohort and four cross-sectional) observed an increase and six (two cohort and four cross-sectional) observed no significant change in sleep quality.

A decline in sleep quality was reported in studies from Chile, Spain, Turkey, Egypt, Italy, the UK and the Netherlands. In Chile, sleep quality among toddlers and preschoolers declined during the COVID-19 pandemic (sleep quality mean score: 5.68 before the pandemic vs 4.93 during the pandemic, p<0.001). Spanish preschoolers showed decreased sleep efficiency during the lockdown (84.3% before the lockdown to 82.2% during the lockdown). A study among school children in Egypt reported that 49.6% had difficulty falling asleep, 42.6% woke up afraid and rushed to parents, 31.4% avoided bedtime and had frequent

| Study | Reported outcome | Measurement tool | Indicator | Before lockdown (mean (SD)) | During lockdown (mean (SD)) | During lockdown (vs before lockdown) P value |
|-------|------------------|------------------|-----------|-----------------------------|-----------------------------|---------------------------------------------|
| Tulchin-Francis et al, 2021, USA | Moderate to vigorous PA (median hours/ day) | mGodin Leisure-Time Exercise Questionnaire | mGodin Leisure-Time Score Index | 56.60 | 44.60 | <0.001 |
| Yang et al, 2020, China | PA level (range 0–5) | IPAQ-long form | PA level (range 0–5) | 2.97 (0.61) | 2.63 (0.68) | <0.01 |
| Zenic et al, 2020, Croatia | Questionnaire prepared by the researchers and reviewed by specialists | Questionnaire prepared by the researchers and reviewed by specialists | % Reporting that they could play limited games at home during lockdown | 57.9% | 57.9% | 0.96 |
| Zengin et al, 2021, Turkey | % Reporting that they could play limited games at home during lockdown | Questionnaire prepared by the researchers and reviewed by specialists | % Reporting that they could play limited games at home during lockdown | 57.9% | 57.9% | 0.96 |

*Adjusted. MET, metabolic equivalent; PA, physical activity.

Table 2 Continued
| Study                        | Measurement tool                                                                 | Indicator                                                                 | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) P value |
|------------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------------|------------------------------|---------------------------------------------|
| Aguilar-Farias et al, 2020, Chile | Adapted from the questions included in the International Study of Movement Behaviours in the Early Years (SUNRISE), pilot-tested | Recreational screen time (hours/day)                                       | 1.66 (1.15)                  | 3.05 (1.92)                  | <0.001                                      |
| Brzek et al, 2021, Poland     | Questionnaire related to the use of electronic devices before and during the COVID-19 restrictions | Average time spent on electronic devices (minutes/week)                     | 940.9                       | 1517.8                       | <0.001                                      |
| Çakıroğlu et al, 2021, Turkey | Turkish adapted version of Internet Gaming Disorder Questionnaire (IGDQ)         | Weekly hours spent playing digital games                                    | 10.67 (10.37)               | 16.15 (13.07)               | <0.001                                      |
| Cardy et al, 2021, Canada     | Adapted from existing instruments (Questionnaire developed by Moore et al, CoRonavruS Health Impact Survey (CRISIS) Adapted for Autism and Related Neurodevelopmental conditions (AFAR)) | Daily screen time (hours) ASD Group (Weekdays)                              | 3.30 (2.92, 3.63)           | 6.90 (6.49, 7.21)            | <0.001                                      |
| Cardy et al, 2021, Canada     | Adapted from existing instruments (Questionnaire developed by Moore et al, CoRonavruS Health Impact Survey (CRISIS) Adapted for Autism and Related Neurodevelopmental conditions (AFAR)) | ASD Group (Weekends)                                                      | 4.90 (4.55, 5.27)           | 6.30 (5.91, 6.63)           | <0.001                                      |
| Carrillo-Diaz et al, 2021, Spain | CERM (Questionnaire of Experiences Related to Cell Phones)                       | Use of mobile phone (CERM Score, range: 10–40, higher score indicates higher use) | 18.40 (7.00)                | 22.10 (8.60)                | <0.01                                       |
| Censi et al, 2021, Italy      | Eating Behaviours Physical Activity and Lifestyle-COVID-19 (EBPAL-COVID-19) questionnaire | % Reporting their children spent more time (a little or a lot) in front of TV or on a smartphone/tablet |                             |                              | 90.9%                                       |
| Chakraborty et al, 2021, India | Self-designed questionnaire (reviewed by independent psychiatrists and clinical psychologists and pre-tested) | % Reporting their child engages in mobile phone more during lockdown         |                             |                              | 63.4%                                       |
| Chambonniere et al, 2021, France | Questionnaires developed based on the IPAQ and ONAPS-Q questionnaires in adults and Youth Risk Behaviour Surveillance System (YRBSS) investigation in children and adolescents | % Reporting increased screen time                                           |                             |                              |                                              |
|                             |                                                                                   | Children                                                                   |                              |                              | 62.0%                                       |
|                             |                                                                                   | Adolescents                                                                |                              |                              | 68.9%                                       |
| Study                          | Measurement tool                                                                 | Indicator                                      | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) P value | Reported outcome                                                                 |
|-------------------------------|----------------------------------------------------------------------------------|-----------------------------------------------|----------------------------|----------------------------|---------------------------------------------|--------------------------------------------------------------------------------|
| Cheng et al., 2021, Malaysia   | Not reported                                                                      | Screen time (hours/day)                       | 2.00 (1.00–3.00)           | 5.50 (4.00–7.75)            | 0.001                                       |                                                                                 |
|                               |                                                                                  | Type 1 diabetes, male                         |                            |                            |                                             |                                                                                 |
|                               |                                                                                  | 2.00 (1.00–3.00)                              |                            |                            |                                             |                                                                                 |
|                               |                                                                                  | Type 1 diabetes, female                       | 1.00 (1.00–3.00)           | 5.00 (3.00–7.00)            | <0.001                                      |                                                                                 |
|                               |                                                                                  | Type 2 diabetes, male                         | 3.05 (1.71)                | 5.90 (3.25)                | 0.001                                       |                                                                                 |
|                               |                                                                                  | Type 2 diabetes, female                       | 1.81 (1.50)                | 5.21 (3.57)                | <0.001                                      |                                                                                 |
| Clarke et al., 2021, UK       | Topic guide for in-depth interviews to get insights into the perceived impact of lockdown restrictions on preschool children’s physical activity, sedentary behaviour, food intake and sleep | Children’s screen time                        |                            |                            |                                             |                                                                                 |
| Eyler et al., 2021, USA       | Interview guide to assess parents’ perceptions of their child’s PA and screen time during COVID-19 stay-at-home orders (pilot-tested) | Parents’ perception about change in their children’s screen time from before to during lockdown |                            |                            | Increased                                   |                                                                                 |
| Garcia et al., 2021, USA      | Adapted from the National Survey of Children’s Health                            | Screen time in weekdays (hours/day)          | 3.69 (2.66)                | 6.25 (4.24)                | 0.007                                       |                                                                                 |
|                               |                                                                                  | Screen time in weekends (hours/day)          | 5.94 (3.58)                | 7.39 (3.93)                | 0.004                                       |                                                                                 |
| Guo et al., 2021, China       | Changes in screen time assessed with the question, ‘Compare with the 3 months before the outbreak of COVID-19, is there any difference in the daily time you (or your child) spend in using screen-based media (ie, cell phone, computer, or pad)?’ | % Reporting increased screen time             |                            |                            | 76.9%                                       |                                                                                 |
| Kolota and Głąbska, 2021, Poland | Short-Form Survey Instruments for Children’s Diet, Physical Activity and Sedentary Behaviour | % Watching television for ≥2 hours per day | 78.3%                     | 88.4%                      | <0.001                                      |                                                                                 |
| Lim et al., 2020, Singapore   | Questionnaire which included information on recreational screen time             | Non-academic screen time (hours/day)          | 1.61 (1.17)                | 3.15 (2.19)                |                                             |                                                                                 |
| López-Bueno et al, 2020, Spain| Screen exposure assessed with the question, ‘How many hours is your child usually exposed to screens such as TV, cell phone, and tablet daily?’ | Screen exposure (hours/day)                   | 2.00 (1.60)                | 4.90 (2.30)                | <0.001                                      |                                                                                 |
| Study                          | Measurement tool                                           | Indicator                                                                 | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) P value | P value |
|-------------------------------|------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------|------------------------------|------------------------------------------|---------|
| Łuszczki et al, 2021, Poland | Questionnaire related to the use of technical devices and the internet by children | Time spent watching movies or programmes on the internet or TV (hours/day) | Weekdays 2.12 (1.00)        | 2.34 (1.12)                  | 0.032                                    |         |
|                              |                                                            |                                                                           | Weekend 2.81 (1.04)         | 2.70 (1.10)                  | 0.028                                    |         |
| Masi et al, 2021, Australia  | Questionnaire developed by the investigators and pilot tested with clinicians, researchers and a small group of parents | % Reporting their children were watching more television or using digital media during lockdown |                             |                              | 81.6%                                    |         |
| Medrano et al, 2021, Spain   | ‘The Youth Activity Profile’ questionnaire (YAP)           | Screen time (hours/day)                                                  | 4.30 (2.40)                | 6.10 (2.40)                  | <0.001                                    |         |
| Mitra et al, 2020, Canada     | Secondary data (parents reported time spent on various movement behaviours) | % Reporting increased screen time during lockdown compared with before the lockdown |                             |                              | 78.8%                                    |         |
| Monteiro et al, 2021, Portugal| Questionnaire on parents’ perceptions about increased exposure to screens during the lockdown on a five-point Likert-type scale (from ‘1—strongly disagree’ to ‘5—totally agree) | % Who agreed increase in exposure time to TV during lockdown compared with before the lockdown |                             |                              | 71.0%                                    |         |
| Moore et al, 2020, Canada     | Secondary data (change in child’s movement and play behaviours), test-retest (1 week) reliability assessed | Change in watching television or screens from before to during the lockdown (range: 1–5, 3=no change) |                             |                              | Children: 4.10 (0.87) Youth: 4.21 (0.92) |         |
| Morgül et al, 2020, UK        | Family daily routines and children’s emotional and behavioural symptoms questionnaire developed by Orgilés et al | % Using screen >2 hours                                                  | 43.0%                      | 58.4%                        |                                          |         |
| Munasinghe et al, 2020, Australia | Adolescent Sedentary Activities Questions (baseline) Ecological momentary assessment (EMA) (follow-up) | Change in screen time (smartphone screen state) from before to during the lockdown |                             |                              | Increased                                 |         |
| Nathan et al, 2021, Australia | Parents reported total weekly time spent in screen-based leisure activities | Leisure screen time (minutes/week)                                       | 794.2 (565.5)              | 1194.2 (843.5)               | <0.001                                    |         |
| Ofıu et al, 2021, Turkey      | Questions on daily leisure screen time and compliance with the rules set for screen time | % With daily screen time ≥1 hour                                         | 57.7%                      | 88.9%                        | <0.001                                    |         |
|                              |                                                            | % Complying with the limitation for screen time                           | 88.4%                      | 71.2%                        | <0.001                                    |         |
| Study                        | Measurement tool                                                                 | Indicator                                                                 | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) | P value |
|-----------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------|-----------------------------|-------------------------------------|---------|
| Okely et al, 2021, Multi-country \(^a\) | Questionnaire developed by the researchers based on the recommendations for each behaviour guideline, tested, and refined as part of SUNRISE pilot study | Sedentary screen time (minutes/day)                                        | 105.3 (3.6)                 | 162.0 (4.2)                 | 54.9 (38.6, 71.2)*                  | <0.001* |
| Ozturk Eyiymaya and Yalçın İrmak, 2021, Turkey \(^a\) | Questionnaire, which included a question on leisure screen time                   | % Reporting children’s increased screen time (except time spent on academic activities) |                             |                              | 71.7%                               |         |
| Pietrobelli et al, 2020, Italy \(^a\) | Questionnaire which included question on leisure screen time                    | Screen time (hours/day)                                                   | 2.76 (1.64)                 | 7.61 (2.13)                 |                                     | <0.001  |
| Pombo et al, 2021, Portugal \(^a\) | Questionnaire developed by the researchers, questions validated by child development experts and pilot tested | % Spending more or much more time on screen during lockdown                |                             |                              | 71.3%                               |         |
| Sá et al, 2021, Brazil \(^a\) | Questionnaire created by the research team, elaborated by experts in the field, and tested | % Spending more or much more time on screen (playful screen time) during lockdown compared with before the lockdown |                             |                              | 74.8%                               |         |
| Saxena et al, 2021, India \(^a\) | Questions on the duration of digital device use and duration of watching TV     | Time spent using digital devices (hours/week)                              | 6.20                        | 19.80                       |                                     | <0.001  |
|                                   |                                                                                  | Time spent watching TV (hours/week)                                       | 12.20                       | 13.40                       |                                     | <0.001  |
| Schmidt et al, 2020, Germany \(^a\) | The MoMo PA questionnaire                                                       | Total recreational screen time (minutes/day)                              | 133.3 (123.1)               | 194.5 (141.3)               |                                     | <0.01   |
|                                   |                                                                                  | Screen time guideline adherence (%)                                       | 60.9%                       | 37.6%                       |                                     | <0.01   |
| Sciberras et al, 2020, Australia \(^a\) | CoRonavIruS Health Impact Survey                                                  | TV time (OR)                                                              | 1.00                        | 4.00 (2.50, 6.50)           |                                     |         |
| Serra et al, 2021, Italy \(^a\) | Test conceived and made by paediatricians                                       | % Using smartphone ≥4 hours/day                                           | 16.3%                       | 66.3%                       |                                     |         |

Continued
| Study                                | Measurement tool                                                                 | Indicator                                      | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) | P value |
|--------------------------------------|----------------------------------------------------------------------------------|-----------------------------------------------|------------------------------|------------------------------|-------------------------------------|---------|
| ten Velde et al., 2021, Netherlands  | Questionnaire, which included questions on hours of leisure screen time per day on a weekday and a weekend day | Weekday screen time (minutes/day)            | Cohort A: 132.0 (109.0)     | Cohort A: 164.0 (123.0)      | Cohort B: 181.0 (118.0)            | <0.01   |
|                                      |                                                                                  | Weekend Screen time (minutes/day)             | Cohort A: 215.0 (141.0)     | Cohort A: 232.0 (150.0)      | Cohort B: 240.0 (118.0)            |         |
| Tso et al., 2020, Hong Kong          | Questionnaire developed by the research team with input from experts, pilot-tested | Weekday time spent on electronic devices (hours/day) | 1.32 (1.43)                 | 2.31 (1.76)                  |                                     | <0.001  |
| Werling et al., 2021, Switzerland    | Adapted version of “Problematic Use of the Internet-Screening Questionnaire for Children and Adolescents (PUI-SQ)” | Total media time (hours/day)                  | 3.89                        | 6.76                        |                                     |         |
| Werling et al., 2021, Switzerland    | Adapted version of PUI-SQ                                                        | Total media time (hours/day), male            | 4.47 (3.21)                 | 7.51 (4.85)                  |                                     | <0.001  |
|                                      |                                                                                  | Total media time (hours/day), female          | 4.77 (3.08)                 | 7.12 (3.87)                  |                                     | <0.001  |
| Yang et al., 2020, China             | International Physical Activity Questionnaire-long form                          | Median screen time (hours/day)                | 4.00                        | 5.00                        |                                     | <0.001  |

*Adjusted.
ASD, autism spectrum disorder; PA, physical activity; TV, television.
| Study | Measurement tool | Indicator | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) P value |
|-------|------------------|-----------|----------------------------|-----------------------------|------------------------------------------|
| Adibelli and Sümen, 2020, Turkey | Questionnaire prepared by the research team (increase in sleep time during the pandemic) | % With increased tendency to sleep | | | 34.2% |
| Aguilar-Farias et al., 2020, Chile | Adapted from the questions included in the International Study of Movement Behaviours in the Early Years (SUNRISE), pilot-tested | Sleep duration (hours/day) | 10.92 (1.80) | 11.01 (1.86) | 0.001 |
| | | Sleep quality (Mean score, range: 1–7) | 5.68 (1.54) | 4.93 (1.77) | <0.001 |
| Alonso-Martínez et al., 2021, Spain | Wrist-worn GENEActiv tri-axial accelerometer | Sleep duration (hours/day) | 9.51 (0.74) | 9.54 (1.30) | 0.914 |
| | | Sleep efficiency (%) | 84.3% | 82.2% | 0.047 |
| AMHSI, 2020, Multi-country | Newly designed sleep-wake patterns questionnaire and daily log adapted from Sleep Diary/Sleep Log of the National Sleep Foundation (NFS, USA) | Sleep duration | 8:36 (1:20) | 9:34 (0:24) | 0.05 |
| Araby et al., 2021, Egypt | Questionnaire adapted and translated from CDC fact sheet about stressful effects of COVID-19 pandemic on children and teens, 2020 | % With a change of sleep pattern from before to during the lockdown | Change of bedtime | Difficulty to fall asleep | 88.3% |
| | | | Wake up afraid and rush to parents | 49.6% |
| | | | Avoid bedtime | 42.6% |
| | | | Return to bedwetting | 31.4% |
| | | | Frequent nightmares | 6.6% |
| Brzek et al., 2021, Poland | Questionnaire related to sleeping behaviours during the pandemic period in comparison to the previous period | Sleep duration per 24 hours (hours) | 9.74 (1.18) | 10.11 (1.21) | <0.001 |
| Cacioppo et al., 2020, France | Questionnaire developed by a national multidisciplinary group experienced in disability care, pilot-tested | % Reporting increased sleeping difficulties in children during lockdown | | | 22.0% |

Continued
| Study                           | Measurement tool                                | Indicator                                                                 | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) | P value |
|--------------------------------|------------------------------------------------|--------------------------------------------------------------------------|-----------------------------|-----------------------------|-------------------------------------|---------|
| Cellini et al, 2021, Italy     | Sleep Disturbance Scale for Children            | Time in bed (hours)                                                      | 9.37 (0.05)                 | 10.21 (0.05)                |                                     | <0.001  |
|                                |                                                 | Bedtime (hour:mm)                                                       | 21:30 (0.03)                | 22:48 (0.03)                |                                     | <0.001  |
|                                |                                                 | Rise time (hour:mm)                                                     | 07:11 (0:04)                | 09:01 (0:04)                |                                     | <0.001  |
|                                |                                                 | Sleep quality (Sleep Disturbance Scale total score; higher scores indicate greater severity of sleep disturbance) | 38.60 (0.58)                | 39.90 (0.58)                |                                     | 0.027   |
| Cerasuolo, 2021, Italy         | Children's Sleep Habits Questionnaire (CSHQ)    | Bedtime in toddlers and preschoolers (weekdays and weekends)             |                             |                             | Delayed                             | <0.01   |
|                                |                                                 | Rise time in toddlers and preschoolers (weekdays)                       |                             |                             | Delayed                             | <0.01   |
|                                |                                                 | Rise time in toddlers and preschoolers (weekdays)                       |                             |                             | Delayed                             | <0.01   |
|                                |                                                 | Rise time in toddlers and preschoolers (weekends)                       |                             |                             | No change                           |         |
|                                |                                                 | CSHQ total score (higher score indicates more disturbed sleep)          | Toddlers 47.51 (8.26)       | 46.82 (8.10)                | Not significant                     | 0.020   |
|                                |                                                 | Toddler 51.12 (6.36)                                                    |                             |                             |                                     |         |
|                                |                                                 | Preschooler 47.82 (8.08)                                                |                             |                             |                                     |         |
| Cheng et al, 2021, Malaysia    | Not reported                                    | Sleep duration (hours)                                                  | T1DM, Male 8.07 (1.21)      | 9.06 (1.39)                 |                                     | 0.033   |
|                                |                                                 | T1DM, Female 8.18 (1.31)                                                |                             |                             |                                     | <0.001  |
|                                |                                                 | T2DM, Male 7.80 (0.71)                                                  |                             |                             |                                     | 0.001   |
|                                |                                                 | T2DM, Female 7.64 (1.12)                                                |                             |                             |                                     | <0.001  |
| Clarke et al, 2021, UK         | Topic guide for in-depth interviews to get insights into the perceived impact of lockdown restrictions on preschool children's physical activity, sedentary behaviour, food intake, and sleep | Children's sleep quality                                                | Many reported difficulties in getting their child to sleep | | | |

Continued
| Study                        | Measurement tool                                                                 | Indicator                                                                 | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) | P value |
|-----------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------|-----------------------------|-------------------------------------|---------|
| Di Giorgio et al, 2020, Italy | Sleep Disturbance Scale for Children                                             | Sleep Disturbance Scale for Children                                       | No change                   |                             |                                     | 0.970   |
| Di Giorgio et al, 2021, Italy | Ad-hoc created questions about their children's sleep habits                     | % Sleeping 8–11 hours per night                                           | 73.0%                       | 73.0%                       |                                     | 0.001   |
| Dondì et al, 2021, Italy     | Adapted from the Sleep Disturbance Scale for Children (SDSC)                    | % Reporting more difficulty in falling asleep during lockdown              | 69.3%                       |                             |                                     |         |
| Garcia et al, 2021, USA      | Adapted from the National Survey of Children's Health                           | Hours of sleep/weekday                                                     | 8.72 (1.77)                 | 9.36 (1.5)                  | 0.16                                |         |
|                             |                                                                                  | Hours of sleep/weekend                                                     | 9.47 (2.03)                 | 10 (1.37)                   | 0.2                                 |         |
| Guo et al, 2021, China       | Change in sleep assessed with the question “Compare with the three months before the outbreak of COVID-19, is there any change in the amount of you (or your child) daily sleeping?” | % Reporting no difference in sleep duration                               |                             |                             | 47.5%                              |         |
| Kaditis et al, 2021, Multi-country | Bedtime on weekdays and on weekends                                               | Delayed                                                                   | <0.01                       |                             |                                     |         |
|                             | Wake time on weekdays and on weekends                                            | Delayed                                                                   | <0.01                       |                             |                                     |         |
|                             | Sleep duration on weekdays                                                       | Increased                                                                 | <0.001                      |                             |                                     |         |
|                             | Sleep duration on weekends                                                       | No change                                                                | 0.51                        |                             |                                     |         |
| Kahn et al, 2021, USA        | Objective sleep metrics recorded via videosomnography in the naturalistic home-setting, using Nanit camera monitors | Nighttime sleep duration (Mean difference)                                | 11.0 min                    |                             | 0.01                                |         |
|                             | Morning rise time (Mean difference)                                              | 9.5 min                                                                  | 0.008                       |                             |                                     |         |
| Lavigne-Cerván et al, 2021, Spain | BEARS (Sleep screening tool)                                                     | Sleep quality (BEARS Score-screening for sleep disorder)                 | 7.40                        | 13.18                       | 0.01                                |         |

Continued
| Study                  | Measurement tool                                                                 | Indicator                                    | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) | P value |
|-----------------------|----------------------------------------------------------------------------------|----------------------------------------------|------------------------------|------------------------------|-------------------------------------|---------|
| Li et al, 2021, China | Pittsburgh Sleep Quality Index (PSQI)                                           | Sleep duration (hours/day)                   | 6.73 (SE 0.05)               | 7.18 (SE 0.06)               |                                     | 0.001   |
|                       |                                                                                  | Bedtime                                      | 22:57:52 (SE 0:02:05)        | 23:22:13 (SE 0:03:02)        |                                     | 0.001   |
|                       |                                                                                  | Wake-up time                                 | 06:45:26 (SE 0:01:54)        | 08:05:48 (SE 0:03:08)        |                                     | 0.001   |
|                       |                                                                                  | Sleep quality (score, higher score indicates lower quality) | 6.99 (SE 0.09)               | 6.19 (SE 0.09)               |                                     | <0.001  |
| Lim et al, 2020, Singapore | Questionnaire which included information on sleeping patterns of children        | Sleep duration (hours/day)                   | 9.29 (1.00)                  | 9.63 (1.18)                  |                                     | <0.001  |
|                       |                                                                                  | Bedtime (hour:mm)                            | 21:36 (1.02)                 | 22:05 (1.25)                 |                                     | <0.001  |
|                       |                                                                                  | Rise time (hour:mm)                          | 06:45 (0:58)                 | 07:49 (0:90)                 |                                     | <0.001  |
| Liu et al, 2020, China | Children's Sleep Habit Questionnaire (CSHQ)                                     | Nocturnal sleep duration (hours/day)         | Weekday: 9.47 (0.63)         | 10:38 (1.05)                 |                                     | <0.001  |
|                       |                                                                                  |                                                             | Weekend: 9.88 (0.78)         |                             |                                     |         |
|                       |                                                                                  | Bedtime (hour:min)                            | 21:30 (0.03)                 | 22:48 (0.03)                 |                                     | <0.001  |
|                       |                                                                                  | Rise time (hour:min)                          | 07:11 (0:04)                 | 09:01 (0:04)                 |                                     | <0.001  |
|                       |                                                                                  | Total Children’s Sleep Habits Questionnaire Score (higher score indicates lower sleep quality) | 51.87 (6.77)                 | 44.28 (6.06)                 |                                     | <0.001  |
| Lokhandwala et al, 2021, USA | Actigraphy data together with daily sleep diary (for validation)     | 24-hour sleep duration (minutes)              | 628.6 (29.4)                 | 631.6 (30.7)                 |                                     | 0.631   |
|                       |                                                                                  | Sleep efficiency (%)                          | 84.9 (4.6)                   | 85.4 (4.5)                   |                                     | 0.365   |
| López-Bueno et al, 2020, Spain | Sleep duration assessed with the question “How many hours does your child usually sleep daily?” | Sleep duration (hours/day)                   | 9.10 (1.20)                  | 9.20 (1.60)                  |                                     | 0.129   |
| Luijten et al, 2021, Netherlands | Patient-Reported Outcome Measurement Information System (PROMIS) scale | PROMIS Sleep Related Impairment Score (higher score indicates greater sleep impairment) | 47.60 (10.00)               | 49.90 (8.70)                 |                                     | <0.01   |
Table 4  Continued

| Study                      | Measurement tool                                                                 | Indicator                                                                 | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) P value | P value |
|----------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------|-----------------------------|---------------------------------------------|---------|
| Łuszczki et al, 2021, Poland\(^{51}\) | Assessed with the questions "What is the amount of time you sleep during a 24 h period on school days? What is the amount of time you sleep during a 24 h period on weekends? During the past month, how would you rate your sleep quality overall?" | Weekdays sleep duration (hours)                                            | 8.83 (1.64)                 | 8.55 (1.17)                 | <0.001                                       | <0.001  |
|                            |                                                                                 | Weekends sleep duration (hours)                                           | 10.11 (1.45)                | 9.52 (1.36)                 |                                             |         |
|                            |                                                                                 | Sleep quality (Score, higher score indicates better quality)              | 1.70 (0.68)                 | 1.78 (0.65)                 |                                             | 0.032   |
| Łuszczki et al, 2021, Poland\(^{51}\) | Assessed with the questions "What is the amount of time you sleep during a 24 h period on school days? What is the amount of time you sleep during a 24 h period on weekends? During the past month, how would you rate your sleep quality overall?" | % Reporting reduction in children’s sleep quality                          |                             |                                             |                                             |         |
| Masi et al, 2021, Australia\(^{52}\) | Questionnaire developed by the investigators and pilot tested with clinicians, researchers, and a small group of parents | % Reporting reduction in children’s sleep quality                          |                             |                                             |                                             | 43.6%   |
| Medrano et al, 2021, Spain\(^{52}\) | Sleep time calculated from children’s daily log of wake-up time and bedtime | Weekdays sleep duration (hours/day)                                       | 9.10 (0.90)                 | 9.90 (1.20)                 | <0.001                                       | <0.001  |
|                            |                                                                                 | Weekend days sleep duration (hours/day)                                   | 9.40 (1.10)                 | 10.10 (1.60)                |                                             |         |
| Mitra et al, 2020, Canada\(^{53}\) | Secondary data (parents reported time spent on various movement behaviours)   | % Reporting same sleep duration during lockdown compared to before the lockdown |                             |                                             |                                             | 51.8%   |
|                            |                                                                                 | % Reporting same sleep quality                                             |                             |                                             |                                             | 68.7%   |
| Moore, 2020, Canada\(^{27}\) | Secondary data (change in child’s movement and play behaviours), test-retest (one-week) reliability assessed | Change in sleep quantity from before to during the lockdown (range: 1–5, 1 = a lot less, 3 = no change, 5 = a lot more) | Children: 3.21 (0.70)       | Children: 3.05 (0.66)       |                                             |         |
|                            |                                                                                 | Change in sleep quality from before to during the lockdown (range: 1–5, 1 = a lot worse, 3 = no change, 5 = a lot better) | Youth: 3.63 (0.84)          | Youth: 3.04 (0.73)          |                                             |         |

Table 4  Continued
| Study | Measurement tool | Indicator | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) | P value |
|-------|------------------|-----------|----------------------------|-----------------------------|------------------------------------|---------|
| Morgü et al, 2020, UK | Family daily routines and children’s emotional and behavioural symptoms questionnaire developed by Orgilés et al | Sleep duration (hours/day) | 9.93 (1.45) | 9.55 (1.76) | <0.01 |
| Munasinghe et al, 2020, Australia | Self-reported 24-hour sleep duration collected via weekly Ecological momentary assessment (EMA) | Median sleep hours (OR) | 1.00 | 1.19 (0.57, 2.51) |  |
| Nathan, 2021, Australia | Sleep duration assessed from hours and minutes of sleep reported during the night and the day | Sleep (min/day) | 614.8 (48.5) | 612.8 (67.0) | 0.639 |
| Okely et al, 2021, Multi-country | Questionnaire developed by the researchers based on the recommendations for each behaviour guideline, tested, and refined as part of SUNRISE pilot study | 24-hour sleep duration (min) | 664.7 (2.9) | 641.2 (3.2) | -9.2 (−28.9, 10.6) | 0.341 |
| | | Bedtime (24 hour:min) | 21:20 (0:02) | 22:01 (0:03) | 0.34 (0:14, 0:54)* | 0.003* |
| | | Wakeup (24 hour:min) | 7:09 (0:02) | 8:09 (0:03) | 0.59 (0:34, 1:23)* | <0.001* |
| | | % With poor sleep quality | 5.1 (1.0) | 6.0 (0.9) | 0.6 (0.1, 1.5)* | 0.267* |
| Pietrobelli et al, 2020, Italy | Questionnaire which included question on sleep behaviour | Sleep time (hours/day) | 8.46 (0.85) | 9.11 (1.10) | 0.003 |
| Pombo et al, 2021, Portugal | Questionnaire developed by the researchers, questions validated by child development experts, and pilot tested | % Spending neither more nor less time on sleep during lockdown | 51.6% |  |
| Ramos Socarras et al, 2021, Canada | Questions derived from the Pittsburgh Sleep Quality Index (PSQI) | Bedtime | Delayed | <0.001 |
| | | Subjective sleep quality | Improved | <0.01 |
| Sá et al, 2021, Brazil | Questionnaire created by the research team, elaborated by experts in the field, and tested | % Spending not more or not less time on sleep during lockdown compared to before the lockdown | 47.7% |  |
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nightmares and 6.6% returned to bedwetting during the COVID-19 lockdown.80 Sixty-nine per cent of Italian children and adolescents reported having more difficulty in falling asleep during the lockdown.81 In contrast, Chinese preschoolers and teenagers had better quality sleep during the COVID-19 lockdown compared with before the pandemic.73 74  Children in Canada and Poland also experienced better quality sleep during the lockdown.27 51 79 A multicountry longitudinal study among children aged 3–5 years old reported no significant change in the proportion of children with poor sleep quality from before to during the lockdown.26

Movement behaviours among children and adolescents with health conditions

Fourteen studies85–98 assessed the impact of COVID-19-related lockdown on movement behaviours (physical activity: 10, screen time: 9, sleep duration: 4, and sleep quality: 4) of children with health conditions such as autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), type 1 and type 2 diabetes, obesity, physical disability, neurodevelopmental disability, psychiatric disorder, fragile X-syndrome, and dental wear.

Almost all the studies reported that the movement behaviours of children and adolescents with health conditions worsened during the lockdown, except two studies that reported no significant change in physical activity85 and sleep quality.85 92 Italian children with obesity spent 2.30 hours less per week in sports during the lockdown than before the lockdown.94 Australian children with ADHD also had less exercise (OR 0.4, 95% CI 0.3, 0.6, p=0.003) during the pandemic than before the pandemic.95 In Italy, children with obesity spent 4.85 hours more on screen daily during the lockdown, reaching an alarming level of 7.61 hours per day of screen time.94 Canadian children and adolescents with ASD increased their daily screen time from 3.3 hours before the lockdown to 6.6 hours daily screen time from 3.3 hours before the lockdown to 6.6 hours during the lockdown, reaching an alarming level of 7.61 hours per day of screen time.94 Turkish children with ASD showed increased sleep problems during the lockdown than before the pandemic.94

Certainty of evidence

Table 5 presents the strength of evidence from quantitative studies on the outcomes. Moderate evidence was observed for decreased physical activity and increased screen time during the COVID-19 lockdown. The evidence for sleep duration and sleep quality was inconclusive.

| Study | Measurement tool | Indicator | Before lockdown (Mean (SD)) | During lockdown (Mean (SD)) | During lockdown (vs before lockdown) | P value |
|-------|------------------|-----------|-----------------------------|-----------------------------|------------------------------------|---------|
| Türkoglu et al, 2020, Turkey66 | Children’s Sleep Habits Questionnaire (CSHQ) | Total Children’s Sleep Habits Questionnaire Score (higher score indicates lower sleep quality) | 47.82 (7.13) | 50.80 (8.15) | - | 0.001 |
| Yang et al, 2020, China66 | International Physical Activity Questionnaire (IPAQ)-long form | Workdays median sleep duration (hours/day) | 8.00 | 8.10 | - | <0.001 |
| Yang et al, 2020, China66 | International Physical Activity Questionnaire (IPAQ)-long form | Weekends median sleep duration (hours/day) | 8.50 | 9.00 | - | <0.001 |
| Zengin et al, 2021, Turkey61 | Questionnaire prepared by the researchers and reviewed by specialists | % With an increased sleep time | 46.4% | 56.8% | 39.0% | 39.0% |
| Zengin et al, 2021, Turkey61 | Questionnaire prepared by the researchers and reviewed by specialists | % Sleeping late | 5.3% | 5.3% | 39.0% | 39.0% |
| Zengin et al, 2021, Turkey61 | Questionnaire prepared by the researchers and reviewed by specialists | % Getting up late | 39.0% | 39.0% | 39.0% | 39.0% |

*Adjusted. T1DM, type 1 diabetes mellitus.

DISCUSSION

Lockdown measures to contain COVID-19 spread had mostly negative consequences on the movement behaviours of children and adolescents worldwide. The majority of children and adolescents experienced longer and less active days. The evidence for increased sleep duration and sleep quality was inconclusive.

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| Zengin et al, 2021, Turkey61 | Questionnaire prepared by the researchers and reviewed by specialists | % Getting up late | 39.0% | 39.0% | 39.0% | 39.0% |

*Adjusted. T1DM, type 1 diabetes mellitus.

14 of 33 studies assessed the impact of COVID-19 lockdown on movement behaviours (physical activity: 10, screen time: 9, sleep duration: 4, and sleep quality: 4) of children with health conditions such as autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), type 1 and type 2 diabetes, obesity, physical disability, neurodevelopmental disability, psychiatric disorder, fragile X-syndrome, and dental wear. Almost all the studies reported that the movement behaviours of children and adolescents with health conditions worsened during the lockdown, except two studies that reported no significant change in physical activity85 and sleep quality.85 92 Italian children with obesity spent 2.30 hours less per week in sports during the lockdown than before the lockdown.94 Australian children with ADHD also had less exercise (OR 0.4, 95% CI 0.3, 0.6, p=0.003) during the pandemic than before the pandemic.95 In Italy, children with obesity spent 4.85 hours more on screen daily during the lockdown, reaching an alarming level of 7.61 hours per day of screen time.94 Canadian children and adolescents with ASD increased their daily screen time from 3.3 hours before the lockdown to 6.6 hours daily screen time from 3.3 hours before the lockdown to 6.6 hours during the lockdown, reaching an alarming level of 7.61 hours per day of screen time.94 Turkish children with ASD showed increased sleep problems during the lockdown than before the pandemic.94

In contrast, Chinese preschoolers and teenagers had better quality sleep during the COVID-19 lockdown compared with before the pandemic.73 74  Children in Canada and Poland also experienced better quality sleep during the lockdown.27 51 79 A multicountry longitudinal study among children aged 3–5 years old reported no significant change in the proportion of children with poor sleep quality from before to during the lockdown.26
of the studies observed a decline in physical activity level among children and adolescents, while some reported no change, and one reported an increase in physical activity during the lockdown. Furthermore, all the studies observed increased screen time in children and adolescents during the lockdown. Most of the studies reported an increase in sleep problems during the pandemic than before the pandemic. Such changes in movement behaviours applied to both apparently healthy children and adolescents, and those with health conditions, with more profound effects observed in the latter group.

According to the majority of the studies in this review, children and adolescents were less active during the COVID-19 restrictions. COVID-19 lockdown created a disabling environment for children to engage in physical activity through home confinement orders and closure of schools and recreation facilities. Among the countries included in this review, Spanish and Brazilian children and adolescents saw the biggest decline in physical activity. These differences in the pattern of physical activity could be attributed to the effect of COVID-19, the degree of lockdown restrictions and the household environment. Spain and Brazil were among the hardest-hit countries by the COVID-19 pandemic, with many COVID-19 infections and deaths. The lockdown restriction in Spain was stringent, and children were not allowed to go outdoors. Most Brazilian children were living in apartments and had limited access to outdoor space for physical activity and sports. Evidence has shown that the availability of bigger outdoor space at the place of residence can positively influence physical activity among children and adolescents both during and before lockdown.

Meanwhile, children and adolescents in some countries could maintain or even increase their physical activity levels during the lockdown restrictions. In Western Australia, children’s physical activity levels did not change from before to during the pandemic. German children and adolescents were more active during the COVID-19 restrictions than before the restrictions, and the proportion of the children and adolescents adhering to physical activity guidelines increased during the lockdown compared with before the lockdown. Several factors might explain these findings, such as the nature of lockdown restrictions, the methodological differences in assessing physical activity and the environment. The lockdown in Western Australia was relatively short, and people were allowed to go outdoors for exercise. Similarly, the lockdown restrictions in Germany were moderate, allowing outdoor activities if done alone or with family members. These two studies in Western Australia and Germany tracked various forms of physical activity across different settings. People in Australia were encouraged to exercise during the restrictions through constant messaging by government officials. They also had a relatively conducive household environment for active indoor and outdoor play for children.

In all the studies, the screen time of children and adolescents increased during the COVID-19 lockdown. Schools were closed, and children were confined inside their homes during the lockdown, resulting in more free time. This increased free time and drastically reduced outdoor time could have led children to spend more time on screen for recreation. Parents’ work conditions during the lockdown might also have affected children’s screen time. Many working parents were asked to telework.

### Table 5: Strength of evidence from quantitative data

| Movement behaviour | Quality* | Quantity† | Consistency‡ | Strength of evidence§ |
|-------------------|----------|-----------|--------------|------------------------|
| Physical activity (PA) | 2 good, 15 fair, 24 poor | 41 | Consistent: 32 studies (78.1%) reported a decrease in PA, 8 (19.5%) reported no significant change in PA, 1 (2.4%) reported an increase in PA during the lockdown | Moderate |
| Screen time | 2 good, 12 fair, 24 poor | 38 | Consistent: All studies (100%) reported an increase in screen time during the lockdown | Moderate |
| Sleep duration | 1 good, 14 fair, 14 poor | 29 | Inconsistent: 14 studies (48.3%) reported increased sleep duration, 13 (44.8%) reported no significant change in sleep duration, 2 (6.9%) reported decreased sleep duration | Inconclusive |
| Sleep quality | 1 good, 9 fair, 12 poor | 22 | Inconsistent: 9 studies (40.9%) reported decreased sleep quality, 8 (36.4%) reported no significant change in sleep quality, 5 (22.7%) reported an increase in sleep quality during the lockdown | Inconclusive |

*Quality score based on the National Institutes of Health tool.
†Number of studies.
‡Evidence inconsistent: when ≤75% of the studies reported the same conclusion.
§Evidence based on quality, number and the outcome of the studies: strong=provided by generally consistent findings in multiple high-quality quantitative studies; moderate=generally consistent findings in one high-quality quantitative study and one low-quality study or in multiple low-quality studies; inconclusive=only one study available or inconsistent findings in multiple studies.

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from home during the lockdown. Children’s screen use behaviour might have been influenced by that of the parents. Children might also have been encouraged by parents to spend their free time on screen to provide a quiet work environment at home for the parents. The relationship between family environment and children’s behaviour has been well established. Confined children and adolescents might use electronic devices more frequently to connect with their peers via social media.

Similar to physical activity, a pattern can be observed in children’s increased screen time related to the degree of restrictions the children faced. The increase in screen time was higher for children in countries with strict lockdowns, such as Spain, Brazil and Turkey, while it was comparatively lower in countries with mild restrictions, such as Germany and Australia.

In nearly half of the studies, children and adolescents increased their sleep duration, and in most of the studies that reported bedtime and wake-up time, children went to bed later and woke up later during the lockdown than before the lockdown. Such change in sleep patterns can be seen as normal because the schools were closed, and children had more free time to relax. They also did not have to wake up early during the lockdown as they did not have to rush to the school. Children were also found to sleep longer during the weekends and holidays before the pandemic. However, relatively longer sleep duration and later bedtime and wake-up time might be a problem for children because they will find it difficult to return to their normal routine once schools resume after the lockdown.

This review has several limitations. First, empirical evidence could not be generated using a meta-analysis. We observed a wide heterogeneity across studies in terms of outcome indicators and their measurements. We also did not have sufficient studies to pool the data for a meta-analysis. Second, a concrete objective measurement of the exposure was difficult. Countries included in this review had different forms and varying degrees of lockdown restrictions. Some of the articles also did not provide sufficient information about the lockdown. We had to base our analysis on the information provided in the article because it was difficult to track the detailed information on lockdowns in different regions of the countries as it changes quickly. However, we tried to categorise the severity of lockdown based on the information provided in the articles. Third, since the studies using objective (device-based) methods for outcomes assessment were very few, we combined them with those using subjective methods. Fourth, most studies reported data from high-income economies, and no study reported data from a low-income economy. This might limit the generalisation of the findings of this review to low- and middle-income settings. Next, most studies collected data using online self-reported questionnaires, as it was the most feasible option during lockdown restrictions; hence, this might have reduced the reliability and validity of the data. Finally, most of the studies used a cross-sectional design, generating a relatively lower quality of evidence. Despite these limitations, this study has some strengths. To the best of our knowledge, it is the first study to comprehensively review the impact of COVID-19 lockdown restrictions on children and adolescents’ movement behaviours. Furthermore, this review searched articles from a wide range of databases at three time points and included a large sample of articles from various countries and territories worldwide.

CONCLUSION
Lockdown restrictions to curb the spread of COVID-19 had a mostly negative effect on children and adolescents’ movement behaviours worldwide. Children spent less time on physical activity and more time on screens during confinement than before the pandemic. However, children and adolescents facing milder restrictions, such as in Germany and Western Australia, where they were allowed to go outdoors for exercise while maintaining social distance, were physically more active and used screens less than those under stricter lockdowns, such as in Spain. Children and adolescents tended to sleep longer hours, with later bedtime and wake-up time during the pandemic than before the pandemic. Acknowledging that unhealthy movement behaviours can negatively affect children and adolescents’ physical, social and psychological health, appropriate actions are essential from all the relevant stakeholders. The findings from this review suggest that the authorities should carefully consider the negative consequences of the measures to contain the spread of infections on the healthy movement behaviours of children and adolescents while applying them, and such measures should be introduced in a way that would have the least effect on children and adolescents’ healthy movement behaviours. Health-related organisations and authorities should emphasise the importance of remaining physically active, especially during a lockdown, and suggest possible ways to do so. Schools should consider having online physical education lessons to engage children in physical activity. Parents should encourage and support their children to engage in physical activity while maintaining social distance. They should also motivate and provide a conducive environment for their children to spend their time in creative activities rather than using the screens. Further studies with robust study designs should be conducted to assess the impact of COVID-19 lockdown on the healthy movement behaviours of children and adolescents. More studies from low-income and middle-income countries could help in improving the understanding of the impact.

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