





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. **PROSPERO registration number** CRD42021245924.

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

Key questions

What is already known?

- Lockdown restrictions to curb the spread of COVID-19 may have affected movement behaviours of children and adolescents.

What are the new findings?

- Lockdown measures to contain the spread of COVID-19 had mostly negative consequences on the movement behaviours of children and adolescents worldwide, with children spending less time on physical activity and more time on screens during confinement than before the pandemic.
- Children and adolescents facing milder restrictions, such that 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.
- Children and adolescents had later bedtime and wake-up time during the pandemic than before the pandemic.

What do the new findings imply?

- When implementing measures to contain the spread of infections, authorities should carefully consider the negative consequences of the measures on the healthy movement behaviours of children and adolescents.
- Such measures should be introduced in a way that would have the least effect on children and adolescents' healthy movement behaviours.

of 13 January 2022.¹ WHO declared a Public Health Emergency of International Concern on 30 January 2020 to accelerate action against the rapidly spreading coronavirus.² 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. In extreme cases, public parks were also closed, and people were not allowed to go out, except for emergencies.³

Lockdown restrictions greatly affected people's lives, especially those of children and adolescents.⁴ Schools, where children and adolescents spend a significant amount of time, were closed for months. Their daily routines changed drastically, and they had more free time. However, as they had limited opportunity to go outdoors due to lockdown restrictions and fear of contracting the virus while being outdoors,⁵ they had to spend most of their time inside their residence. Such confinement of children and adolescents inside their house during this active age can negatively affect their movement behaviours—physical activity, sedentary behaviour and sleep.⁶

Healthy movement behaviours—adequate physical activity, limited sedentary behaviour, and sufficient sleep—are critical for healthy childhood development.⁷ However, these behaviours might be compromised during lockdown restrictions. 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 19 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.²¹ 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, non-essential businesses 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.²⁷

To be more specific, physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure.²⁸ 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.³⁰

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, SocINDEX, 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).³⁸ 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

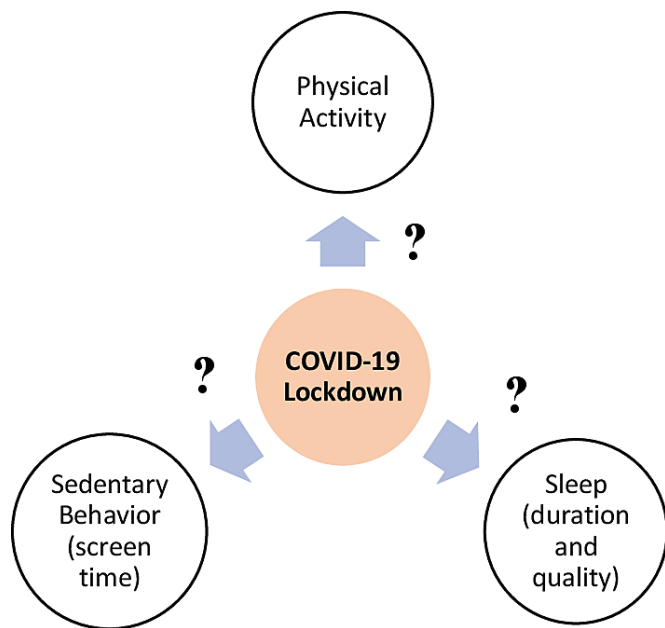


Figure 1 Conceptual framework for the impact of COVID-19 pandemic lockdown on movement and play behaviours of children and adolescents*. *Adapted and modified from WHO's guideline on physical activity, sedentary behaviour and sleep for children under 5 years of age.⁷

Italy; 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 objective, 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)^{3 27 39–61} observed a decline in physical activity, 8 (2 cohort, 5 cross-sectional and 1 qualitative)^{9 20 26 62–66} observed no change and 1 (cohort)¹⁹ 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 Spain³ to 91 min per day in another study from the same country.⁵² In Brazil, 83% of the adolescents spent less or much less time on physical activity during the pandemic than before the pandemic,⁵⁸ and the proportion of physically active children reduced from 59.1% to 7.0% during the same period.⁵⁷ 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.^{27 39 41–51 53 55 56 59–61}

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.^{20 63 65 66} A multicountry longitudinal study also reported no significant change in time spent on total physical activity among children aged 3–5 years old.²⁶ German children and adolescents were found

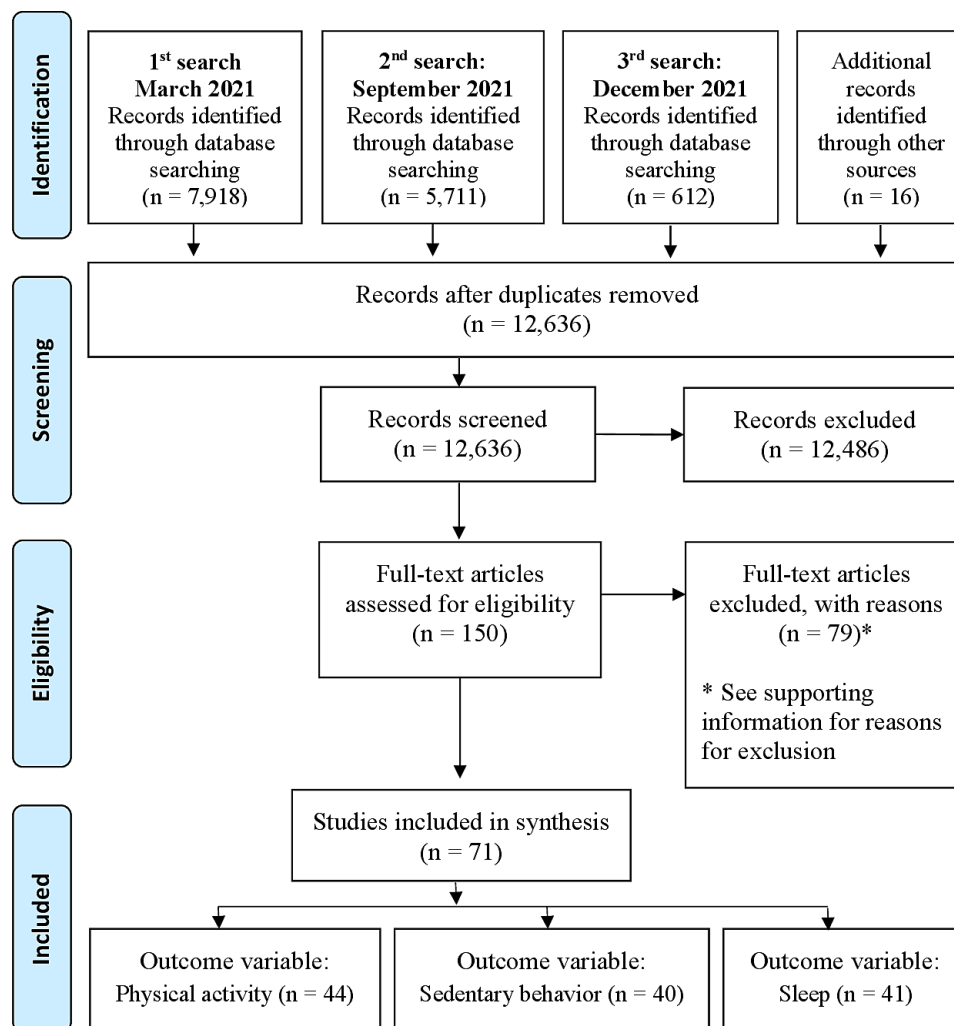


Figure 2 PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

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).¹⁹

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 study²⁶ to 2.9 hours per day in Spain.³ 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.⁵² Singaporean and German children spent daily 1.54 hours and 1.02 hours more, respectively, on screen during the pandemic than before the pandemic.^{19 50} In Italy, 9 out of

10 Italian children spent more time on screen during the lockdown than before the lockdown⁴⁴ 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.⁶⁷ In Brazil, nearly three-fourths of the children reported spending more or much more time on screen during the lockdown than before the pandemic.⁵⁸ Similar findings were reported in studies from Canada, China, Turkey and Portugal.^{49 53 56 68} Approximately two-thirds of the children and adolescents in France and India spent more time on screen during the lockdown than before the lockdown.^{46 69}

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)^{27 39 43 50 52 61 66 70-74} reported an increase, two

Table 1 Characteristics of included studies

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Adebilli and Sümen, 2020, Turkey ⁸⁴	Cross-sectional	Children aged 7–13 years	597	9.87 years (1.99)	55.8%	Implemented lockdown, suspended formal education and practised distance education	Strict lockdown	Sleep quality
Aguilar-Farias <i>et al</i> , 2020, Chile ³⁹	Cross-sectional	Children aged 1–5 years	3157	3.10 years (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 <i>et al</i> , 2021, Spain ⁴⁰	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, sleep duration, sleep quality
AMHSI, 2020, Multicountry ⁷⁰	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 <i>et al</i> , 2021, Egypt ⁸⁰	Cross-sectional	School children aged 6–14 years	1507	Not reported	40.9%	Total lockdown measures	Strict lockdown	Sleep quality
Bingham <i>et al</i> , 2021, UK ⁴¹	Cohort (Prospective)	Children aged 9–13 years	643	9.10 years (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 <i>et al</i> , 2021, Poland ⁴²	Cohort (Prospective)	Adolescent Polish youths	127	15.40 years (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

Continued



Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Brzek <i>et al</i> , 2021, Poland ⁴³	Cohort (Prospective)	Children aged 3–5 years	1316	Not reported	55.6%	School closure, ban on public gatherings,	Strict lockdown	Physical activity, screen time, sleep duration
Cacioppo <i>et al</i> , 2020, France ⁸⁵	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 <i>et al</i> , 2021, Turkey ¹⁰⁵	Cross-sectional (Repeated)	Children and adolescents aged 10–18 years	Before: 581 During: 410	Not reported	Before: 43.9% During: 56.3%	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 <i>et al</i> , 2021, Canada ⁸⁶	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 <i>et al</i> , 2021, Spain ⁸⁷	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 <i>et al</i> , 2021, Italy ⁴⁴	Cross-sectional	Italian children aged 2–11 years	1027	Not reported	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 <i>et al</i> , 2021, Italy ⁷¹	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

Continued

Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Cerasuolo <i>et al</i> , 2021, Italy ⁷⁷	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 <i>et al</i> , 2021, USA ⁴⁵	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 <i>et al</i> , 2021, India ⁶⁹	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 <i>et al</i> , 2021, France ⁴⁶	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

Continued

Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Cheng <i>et al</i> , 2021, Malaysia ⁸⁸	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 <i>et al</i> , 2021, UK ⁴⁷	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 <i>et al</i> , 2020, Italy ⁷⁸	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
DiGiorgio <i>et al</i> , 2021, Italy ⁸⁹	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, screen time, sleep duration, sleep quality

Continued

Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Dondi <i>et al</i> , 2021, Italy ⁸¹	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 ⁹⁰	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 <i>et al</i> , 2021, USA ⁶²	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 <i>et al</i> , 2021, USA ⁴⁸	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 <i>et al</i> , 2021, USA ⁹¹	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

Continued

Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Guo <i>et al</i> , 2021, China ⁴⁹	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 <i>et al</i> , 2021, Multi-country ⁷⁵	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 ⁷²	Cohort (Prospective)	Infants 6–18 months old	610 (2019 Cohort; 293, 2020 COVID-19 Cohort; 317)	2019: 11.8 months (3.5) 2020: 11.9 months (3.7)	2019: 51.5% 2020: 49.8%	Stay-at-home orders imposed in the USA (Los Angeles and San Francisco: 19 March, Chicago: 21 March, New York: 22 March, and Dallas and Houston: 2 April)	Strict lockdown	Nighttime sleep duration, morning rise time
Kofota and Glabaska, 2021, Poland ⁶³	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 <i>et al</i> , 2021, Spain ⁸²	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 <i>et al</i> , 2021, China ⁷³	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

Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Lim <i>et al</i> , 2020, Singapore ⁵⁰	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 <i>et al</i> , 2020, China ⁷⁴	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 <i>et al</i> , 2021, USA ⁷⁶	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 <i>et al</i> , 2020, Spain ³	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 <i>et al</i> , 2021, Netherlands ⁸³	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

Continued

Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Łuszczki <i>et al</i> , 2021, Poland ⁵¹	Cross-sectional (Repeated)	Polish children and adolescents aged 6–15 years	1016 (Before lockdown: 376 During lockdown: 641)	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 <i>et al</i> , 2021, Australia ⁹²	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 <i>et al</i> , 2021, Spain ⁵²	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 <i>et al</i> , 2021, Italy ⁹³	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 <i>et al</i> , 2020, Canada ⁵³	Cross-sectional	Children and youth aged 5–17 years	1472 (5–11 years: 693, 12–17 years: 779)	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 <i>et al</i> , 2021, Portugal ¹⁰⁶	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

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 <i>et al</i> , 2020, Canada ²⁷	Cross-sectional	Children and youth aged 5-17 years	1472 (5-11 years: 53%, 12-17 years: 47%)	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
Morgül <i>et al</i> , 2020, UK ⁵⁴	Cross-sectional	Children aged 5 to 11 years	927	7.45 years (2.04)	45.5%	Lockdown started on 23 rd March, 2020; nationwide school closure except for children of key workers	Moderate lockdown	Physical activity, screen time, sleep duration
Munasinghe <i>et al</i> , 2020, Australia ⁵⁵	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 <i>et al</i> , 2021, Australia ²⁰	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 <i>et al</i> , 2020, Ireland ⁹	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
Ofiu <i>et al</i> , 2021, Turkey ¹⁰⁷	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

Continued

Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Okely <i>et al</i> , 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 Yalçın Irmak, 2021, Turkey ⁸⁸	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 <i>et al</i> , 2020, Italy ⁹⁴	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 <i>et al</i> , 2021, Portugal ⁶⁶	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

Continued

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 <i>et al</i> , 2021, Canada ⁷⁹	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
Ruíz-Roso <i>et al</i> , 2020, Multi-country ⁵⁷	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 <i>et al</i> , 2021, Brazil ⁵⁸	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 <i>et al</i> , 2021, India ¹⁰⁸	Cohort (Prospective)	School children aged 9-14 years	1237	Baseline: 11.88 years (1.01)	40.9%	School closure	Unclear	Screen time
Schmidt <i>et al</i> , 2020, Germany ¹⁹	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 <i>et al</i> , 2020, Australia ⁹⁵	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

Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Serra, 2021, Italy ⁶⁷	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 <i>et al</i> , 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)	57.6%	Nationwide shutdown of schools, sports clubs, bars, and restaurants	Strict lockdown	Physical activity, screen time
Tornaghi <i>et al</i> , 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 <i>et al</i> , 2020, Hong Kong ¹⁰⁸	Cross-sectional	Children aged 2-12 years	29202	6.50 years (2.84)	48.6%	All schools closed	Unclear	Screen time
Tulchin-Francis <i>et al</i> , 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 <i>et al</i> , 2020, Turkey ⁹⁶	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

Continued

Table 1 Continued

Study	Study design	Study population	Sample size	Mean age	Female (%)	Description of lockdown	Classification of lockdown	Outcomes of interest assessed
Werling <i>et al</i> , 2021, Switzerland ⁹⁷	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 <i>et al</i> , 2021, Switzerland ⁹⁸	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 <i>et al</i> , 2020, China ⁶⁶	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 <i>et al</i> , 2020, Croatia ⁶⁰	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 <i>et al</i> , 2021, Turkey ⁶¹	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

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (mean (SD))	During lockdown (mean (SD))	During lockdown (vs before lockdown) P value
Aguilar-Farias <i>et al</i> , 2020, Chile ³⁹	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-Martinez <i>et al</i> , 2021, Spain ⁴⁰	Wrist-worn GENEActiv tri-axial accelerometer	Total PA (minutes/day)	346.9 (54.6)	303.6 (76.5)	0.002
Bingham <i>et al</i> , 2021, UK ⁴¹	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 <i>et al</i> , 2021, Poland ⁴²	Physical Activity Screening Measure	Group not meeting the WHO's MVPA recommendations before lockdown % Maintaining the same insufficient level of PA during lockdown Group meeting the WHO's MVPA recommendations before lockdown % Significantly decreasing their level of MVPA below the recommendations during lockdown		86.6% 50.0%	0.04 0.01
Brzek <i>et al</i> , 2021, Poland ⁴³	Questionnaire related to PA, and it changes during the COVID-19 restrictions	% Physically active	81.1%	67.2%	<0.001
Cacioppo <i>et al</i> , 2020, France ⁸⁵	Questionnaire developed by a national multidisciplinary group experienced in disability care, pilot-tested	% WHO practised PA during lockdown		56.0%	
Carrillo-Diaz <i>et al</i> , 2021, Spain ⁸⁷	Physical Activity Questionnaire (IPAQ-SF)	Physical activity (total minutes of leisure METs per week)	856.6 (343.5)	332.8 (91.6)	<0.01

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Table 2 Continued

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (mean (SD))	During lockdown (mean (SD))	During lockdown (vs before lockdown) P value
Censi <i>et al</i> , 2021, Italy ⁴⁴	Eating Behaviours Physical Activity and Lifestyle-COVID-19 (EBPAL-COVID-19) questionnaire	% Who stopped their habitual PA during lockdown			78.1% <0.001
Chaffee <i>et al</i> , 2021, USA ⁴⁵	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 6 month follow-up before lockdown (baseline vs 6 month follow-up) 6 month follow-up during lockdown (baseline vs 6 month follow-up)	From 53.7% to 52.9%	From 54.0% to 38.1%	0.82 <0.001
Chambonniere <i>et al</i> , 2021, France ⁴⁶	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 <i>et al</i> , 2021, Malaysia ⁶⁸	Physical Activity Questionnaire for Children (PAQ-C) and the Physical Activity Questionnaire for Older Children (PAQ-A) adapted from Crocker <i>et al</i> and Kowalski <i>et al</i>	Physical Activity Questionnaire Score (range: 1–5, higher score indicates a higher level of PA)	Type 1 Diabetes, 2.08 (0.70) Type 1 Diabetes, 2.00 (0.38) Type 2 Diabetes, 1.91 (0.56) Type 2 Diabetes, 1.79 (0.41)	Type 1 Diabetes, 1.77 (0.55) Type 1 Diabetes, 1.89 (0.47) Type 2 Diabetes, 1.59 (0.41) Type 2 Diabetes, 1.62 (0.40)	<0.001 <0.001 0.066 0.063
Clarke <i>et al</i> , 2021, UK ⁴⁷	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

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Table 2 Continued

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (mean (SD))	During lockdown (mean (SD))	During lockdown (vs before lockdown) P value
Di Giorgio <i>et al</i> , 2021, Italy ⁸⁹	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 ⁹⁰	Interview form prepared based on relevant literature and validated through opinions from experts	Barriers to PA			Parents reported barriers for PA
Eyler <i>et al</i> , 2021, USA ⁴⁸	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 <i>et al</i> , 2021, USA ⁶²	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 <i>et al</i> , 2021, USA ⁹¹	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 <i>et al</i> , 2021, China ⁴⁹	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%

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Table 2 Continued

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (mean (SD))	During lockdown (mean (SD))	P value
Kolota and Głabaska, 2021, Poland ⁶³	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 <i>et al</i> , 2020, Singapore ⁵⁰	Questionnaire which included information on physical exercise	Time spent on physical exercise (hours/ day)	1.13 (0.60)	0.91 (0.73)	
López-Bueno <i>et al</i> , 2020, Spain ³	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 <i>et al</i> , 2021, Poland ⁵¹	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 <i>et al</i> , 2021, Australia ⁹²	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 <i>et al</i> , 2021, Spain ⁵²	'The Youth Activity Profile' questionnaire (YAP)	PA (minutes/day)	150.0 (40.0)	63.0 (39.0)	<0.001
Minuto <i>et al</i> , 2021, Italy ⁹³	Not reported	Sports (hours/week)	Age ≥6 years <10 years 4.36 (0.94)	0.14 (0.38)	0.02
			Age ≥10 years <14 years 6.01 (4.06)	1.82 (2.32)	<0.001
			Age ≥14 years <18 years 5.14 (4.20)	2.72 (3.40)	<0.001

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Table 2 Continued

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (mean (SD))	During lockdown (mean (SD))	During lockdown (vs before lockdown) P value
Mitra <i>et al</i> , 2020, Canada ⁵³	Secondary data (parents reported time spent on various movement behaviours)	% With decreased outdoor activities during lockdown compared with before the lockdown			56.0%
Moore <i>et al</i> , 2020, Canada ²⁷	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)		Children: 2.28 (1.22) Youth: 1.96 (1.13)	
Morgül <i>et al</i> , 2020, UK ⁵⁴	Family daily routines and children's emotional and behavioural symptoms questionnaire developed by Orgilés <i>et al</i>	% Engaging in at least 60 min of PA per day	67.3%	51.1%	
Munasinghe <i>et al</i> , 2020, Australia ⁵⁵	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 <i>et al</i> , 2021, Australia ²⁰	Questionnaire adapted from the Healthy Active Preschool Years Study	Total PA (minutes/week)	809.7 (584.4)	835.4 (642.4)	0.647
Ng <i>et al</i> , 2020, Ireland ⁹	PACE+instrument (validated against accelerometers)	% Having less PA during lockdown compared with before the lockdown			49.7%
Okely <i>et al</i> , 2021, Multi-country ²⁶	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*

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Table 2 Continued

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (mean (SD))	During lockdown (mean (SD))	P value
Pietrobelli <i>et al</i> , 2020, Italy ⁶⁴	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 <i>et al</i> , 2021, Portugal ⁵⁶	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 <i>et al</i> , 2020, Multi-country ⁵⁷	International Physical Activity Questionnaire (IPAQ)	% Physically active	27.0%	20.5%	
Sá <i>et al</i> , 2021, Brazil ⁵⁸	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 <i>et al</i> , 2020, Germany ¹⁹	The MoMo PA questionnaire	PA guideline adherence (%)	19.1%	30.2%	<0.01
Sciberras <i>et al</i> , 2020, Australia ³⁵	CoRonavirus Health Impact Survey	Regular exercise (OR)	1.00	0.40 (0.30, 0.60)	
ten Velde <i>et al</i> , 2021, Netherlands ⁶⁴	Cohort A: BAECKE questionnaire (validated) Cohort B: BAECKE questionnaire (validated) Cohort B: Accelerometer (n=64)	Total PA (score, range 1–15)	Cohort A: 9.29 (1.03) Cohort B: 9.03 (1.22)	Cohort A: 8.94 (1.07) Cohort B: 8.89 (1.30)	Cohort A: <0.01 Cohort B: 0.16
Tornaghi <i>et al</i> , 2020, Italy ⁶⁵	IPAQ (Italian language)	Light PA (minutes/day) Moderate-to-vigorous PA (minutes/day) PA level (MET-minutes/week)	252.0 (34.0) 65.0 (18.0)	218.0 (39.0) 48.0 (18.0)	<0.01 <0.01 No significant change

Continued

Table 2 Continued

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (mean (SD))	During lockdown (mean (SD))	During lockdown (vs before lockdown) P value
Tulchin-Francis <i>et al</i> , 2021, USA ⁵⁹	Modified Godin Leisure-Time Exercise Questionnaire	mGodin-Leisure Time Score Index Score (range: 0–119, higher scores indicate more PA)	56.60	44.60	<0.001
Yang <i>et al</i> , 2020, China ⁶⁶	IPAQ-long form	Moderate to vigorous PA (median hours/day)	1.50	1.50	
Zenic <i>et al</i> , 2020, Croatia ⁶⁰	PA Questionnaire for Adolescents	PA level (range 0–5)	2.97 (0.61)	2.63 (0.68)	<0.01
Zengin <i>et al</i> , 2021, Turkey ⁶¹	Questionnaire prepared by the researchers and reviewed by specialists	% Reporting that they could play limited games at home during lockdown			57.9%

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

(both cross-sectional)^{51 54} reported a decrease, and eleven (four cohort and seven cross-sectional)^{3 20 26 40 49 53 55 56 58 75 76} 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.^{39 70 72} Spanish children slept approximately 48 min more on weekdays and approximately 42 min more on weekends during the COVID-19 confinement.⁵² Similar results were observed among preschoolers in China.⁷⁴ Italian and Singaporean children slept approximately 27 min and 20 min more, respectively, during the lockdown than before the lockdown.^{50 71} Studies from the UK and Poland reported that children slept less during the lockdown than before the lockdown.^{51 54} 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.^{3 20 26 40 49 55 56 75 76}

Ten studies^{26 50 61 71 73–75 77–79} compared bedtime and wake-up time and one more study⁷² 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 one⁶¹ reported no change in wake-up time and two^{77 79} 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.⁷⁸ A similar shift in bedtime and wake-up time was observed among Singaporean children.⁵⁰ 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.²⁶

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)^{39 40 47 71 80–83} of them observed a decrease, five (one cohort and four cross-sectional)^{27 51 73 74 79} observed an increase and six (two cohort and four cross-sectional)^{26 53 76–78 84} 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.^{39 40 47 71 80–83} 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, $p < 0.001$).³⁹ Spanish preschoolers showed decreased sleep efficiency during the lockdown (84.3% before the lockdown to 82.2% during the lockdown).⁴⁰ 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

Table 3 Changes in screen time from before to during the lockdown

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown) P value
Aguilar-Farias <i>et al</i> , 2020, Chile ³⁹	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 <i>et al</i> , 2021, Poland ⁴³	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 <i>et al</i> , 2021, Turkey ¹⁰⁵	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 <i>et al</i> , 2021, Canada ⁸⁶	Adapted from existing instruments (Questionnaire developed by Moore <i>et al</i> , CoRonavirus Health Impact Survey (CRISIS) Adapted for Autism and Related Neurodevelopmental conditions (AFAR))	Daily screen time (hours) ASD Group (Weekdays) ASD Group (Weekends)	3.30 (2.92, 3.63) 4.90 (4.55, 5.27)	6.90 (6.49, 7.21) 6.30 (5.91, 6.63)	<0.001 <0.001
Carrillo-Diaz <i>et al</i> , 2021, Spain ⁸⁷	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 <i>et al</i> , 2021, Italy ⁴⁴	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 <i>et al</i> , 2021, India ⁶⁹	Self-designed questionnaire (reviewed by independent psychiatrists and clinical psychologists and pre-tested)	% Reporting their child engages in mobile phone more during lockdown % Reporting their child engages in watching television more during lockdown			63.4% 58.1%
Chamboniere <i>et al</i> , 2021, France ⁴⁶	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 Adolescents			62.0% 68.9%

Continued

Table 3 Continued

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown) P value
Cheng <i>et al</i> , 2021, Malaysia ⁸⁸	Not reported	Screen time (hours/day) Type 1 diabetes, male Type 1 diabetes, female Type 2 diabetes, male Type 2 diabetes, female	2.00 (1.00–3.00) 1.00 (1.00–3.00) 3.05 (1.71) 1.81 (1.50)	5.50 (4.00–7.75) 5.00 (3.00–7.00) 5.90 (3.25) 5.21 (3.57)	0.001 <0.001 0.001 <0.001
Clarke <i>et al</i> , 2021, UK ⁴⁷	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			Most parents reported an increase
Eyler <i>et al</i> , 2021, USA ⁶²	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 <i>et al</i> , 2021, USA ⁹¹	Adapted from the National Survey of Children's Health	Screen time in weekdays (hours/day) Screen time in weekends (hours/day)	3.69 (2.66) 5.94 (3.58)	6.25 (4.24) 7.39 (3.93)	0.007 0.004
Guo <i>et al</i> , 2021, China ⁴⁹	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 Glabska, 2021, Poland ⁶³	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 <i>et al</i> , 2020, Singapore ⁵⁰	Questionnaire which included information on recreational screen time	Non-academic screen time (hours/day)	1.61 (1.17)	3.15 (2.19)	
López-Bueno <i>et al</i> , 2020, Spain ³	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

Continued

Table 3 Continued

Reported outcome		Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown)	P value	
Study	Measurement tool	Indicator				
Kuszczyk <i>et al</i> , 2021, Poland ⁵¹	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)	2.12 (1.00)	2.34 (1.12)	0.032	
			Weekdays	2.81 (1.04)	2.70 (1.10)	0.028
			Weekend			
Masi <i>et al</i> , 2021, Australia ⁹²	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 <i>et al</i> , 2021, Spain ⁵²	'The Youth Activity Profile' questionnaire (YAP)	Screen time (hours/day)	4.30 (2.40)	6.10 (2.40)	<0.001	
Mitra <i>et al</i> , 2020, Canada ⁵³	Secondary data (parents reported time spent on various movement behaviours)	% Reporting increased screen time during lockdown compared with before the lockdown		78.8%		
Monteiro <i>et al</i> , 2021, Portugal ¹⁰⁶	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 <i>et al</i> , 2020, Canada ²⁷	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 <i>et al</i> , 2020, UK ⁵⁴	Family daily routines and children's emotional and behavioural symptoms questionnaire developed by Orgilés <i>et al</i>	% Using screen >2 hours	43.0%	58.4%		
Munasinghe <i>et al</i> , 2020, Australia ⁵⁵	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 <i>et al</i> , 2021, Australia ²⁰	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	
Ofiu <i>et al</i> , 2021, Turkey ¹⁰⁷	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	

Continued

Table 3 Continued

Reported outcome					
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown) P value
Okely <i>et al</i> , 2021, Multi-country ²⁶	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 Eyimaya and Yalçın İrmak, 2021, Turkey ⁶⁸	Questionnaire, which included a question on leisure screen time	% Reporting children's increased screen time (except time spent on academic activities)			71.7%
Pietrobelli <i>et al</i> , 2020, Italy ⁹⁴	Questionnaire which included question on leisure screen time	Screen time (hours/day)	2.76 (1.64)	7.61 (2.13)	<0.001
Pombo <i>et al</i> , 2021, Portugal ⁶⁶	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 <i>et al</i> , 2021, Brazil ⁵⁸	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 <i>et al</i> , 2021, India ¹⁰⁸	Questions on the duration of digital device use and duration of watching TV	Time spent using digital devices (hours/week) Time spent watching TV (hours/week)	6.20 12.20	19.80 13.40	<0.001 <0.001
Schmidt <i>et al</i> , 2020, Germany ¹⁹	The MoMo PA questionnaire	Total recreational screen time (minutes/day) Screen time guideline adherence (%)	133.3 (123.1) 60.9%	194.5 (141.3) 37.6%	<0.01 <0.01
Sciberras <i>et al</i> , 2020, Australia ⁹⁵	CoRonavirus Health Impact Survey	TV time (OR)	1.00	4.00 (2.50, 6.50)	
Serra <i>et al</i> , 2021, Italy ⁶⁷	Test conceived and made by paediatricians	% Using smartphone ≥4 hours/day	16.3%	66.3%	

Continued

Table 3 Continued

Reported outcome		During lockdown (vs before lockdown)			
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	P value
ten Velde <i>et al.</i> , 2021, Netherlands ⁶⁴	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 B: 181.0 (118.0)	Cohort A: 164.0 (123.0) Cohort B: 240.0 (118.0)	Cohort A: <0.01 Cohort B: <0.01
		Weekend Screen time (minutes/day)	Cohort A: 215.0 (141.0)	Cohort A: 232.0 (150.0)	Cohort A: <0.01 Cohort B: 0.55
			Cohort B: 197.0 (131.0)	Cohort B: 260.0 (126.0)	Cohort B: <0.01
Tso <i>et al.</i> , 2020, Hong Kong ¹⁰⁹	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)	
Werling <i>et al.</i> , 2021, Switzerland ⁹⁷	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	<0.001
Werling <i>et al.</i> , 2021, Switzerland ⁹⁸	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 <i>et al.</i> , 2020, China ⁶⁶	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.



Table 4 Changes in sleep duration, bedtime, wake-up time and sleep quality from before to during the lockdown

Reported outcome						
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown)	P value
Adebelli and Smen, 2020, Turkey ⁸⁴	Questionnaire prepared by the research team (increase in sleep time during the pandemic)	% With increased tendency to sleep			34.2%	
Aguilar-Farías et al, 2020, Chile ³⁹	Adapted from the questions included in the International Study of Movement Behaviours in the Early Years (SUNRISE), pilot-tested	Sleep duration (hours/day) Sleep quality (Mean score, range: 1–7)	10.92 (1.80) 5.68 (1.54)	11.01 (1.86) 4.93 (1.77)		0.001 <0.001
Alonso-Martínez et al, 2021, Spain ⁴⁰	Wrist-worn GENEActiv tri-axial accelerometer	Sleep duration (hours/day) Sleep efficiency (%)	9.51 (0.74) 84.3%	9.54 (1.30) 82.2%		0.914 0.047
AMHSI, 2020, Multi-country ⁷⁰	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 ⁸⁰	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 Wake up afraid and rush to parents Avoid bedtime Return to bedwetting Frequent nightmares		88.3% 49.6% 42.6% 31.4% 6.6% 31.4%	
Brzek et al, 2021, Poland ⁴³	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 ⁸⁵	Questionnaire developed by a national multidisciplinary group experienced in disability care, pilot-tested	% Reporting increased sleeping difficulties in children during lockdown			22.0%	

Continued

Table 4 Continued

Reported outcome						
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown)	P value
Cellini <i>et al</i> , 2021, Italy ⁷¹	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 ⁷⁷	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	
Cheng <i>et al</i> , 2021, Malaysia ⁸⁸	Not reported	CSHQ total score (higher score indicates more disturbed sleep)	47.51 (8.26)	46.82 (8.10)		Not significant
		Toddlers Preschoolers	51.12 (6.36)	47.82 (8.08)		0.020
Cheng <i>et al</i> , 2021, Malaysia ⁸⁸	Not reported	Sleep duration (hours)	8.07 (1.21)	9.06 (1.39)		0.033
		T1DM, Male	8.18 (1.31)	9.33 (1.33)		<0.001
		T2DM, Male	7.80 (0.71)	9.65 (0.94)		0.001
		T2DM, Female	7.64 (1.12)	9.55 (1.67)		<0.001
Clarke <i>et al</i> , 2021, UK ⁴⁷	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

Table 4 Continued

Reported outcome						
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown)	P value
DiGiorgio <i>et al</i> , 2020, Italy ⁷⁸	Sleep Disturbance Scale for Children	Sleep Disturbance Scale for Children Score			No change	0.970
Di Giorgio <i>et al</i> , 2021, Italy ⁸⁹	Ad-hoc created questions about their children's sleep habits	% Sleeping 8–11 hours per night % Often having difficulty falling asleep	73.0% 6.0%	73.0% 15.0%		0.001
Dondi <i>et al</i> , 2021, Italy ⁸¹	Adapted from the Sleep Disturbance Scale for Children (SDSC)	% Reporting more difficulty in falling asleep during lockdown		69.3%		
Garcia <i>et al</i> , 2021, USA ⁹¹	Adapted from the National Survey of Children's Health	Hours of sleep/weekday Hours of sleep/weekend	8.72 (1.77) 9.47 (2.03)	9.36 (1.5) 10 (1.37)		0.16 0.2
Guo <i>et al</i> , 2021, China ⁴⁹	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 <i>et al</i> , 2021, Multi-country ⁷⁵		Bedtime on weekdays and on weekends Wake time on weekdays and on weekends Sleep duration on weekdays Sleep duration on weekends			Delayed Delayed Increased No change	<0.01 <0.01 <0.001 0.51
Kahn <i>et al</i> , 2021, USA ⁷²	Objective sleep metrics recorded via videomnography in the naturalistic home-setting, using Nanit camera monitors	Nighttime sleep duration (Mean difference) Morning rise time (Mean difference)			11.0 min 9.5 min	0.01 0.008
Lavigne-Cerván <i>et al</i> , 2021, Spain ⁸²	BEARS (Sleep screening tool)	Sleep quality (BEARS Score-screening for sleep disorder)	7.40	13.18		

Continued

Table 4 Continued

Reported outcome						
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown)	P value
Li <i>et al</i> , 2021, China ⁷³	Pittsburgh Sleep Quality Index (PSQI)	Sleep duration (hours/day) Bedtime	6.73 (SE 0.05) 22:57:52 (SE 0:02:05)	7.18 (SE 0.06) 23:22:13 (SE 0:03:02)		0.001 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 <i>et al</i> , 2020, Singapore ⁵⁰	Questionnaire which included information on sleeping patterns of children	Sleep duration (hours/day) Bedtime (hour:mm) Rise time (hour:mm)	9.29 (1.00) 21:36 (1.02) 06:45 (0:58)	9.63 (1.18) 22:05 (1.25) 07:49 (0.90)		<0.001 <0.001 <0.001
Liu <i>et al</i> , 2020, China ⁷⁴	Children's Sleep Habit Questionnaire (CSHQ)	Nocturnal sleep duration (hours/day)	Weekday: 9.47 (0.63) Weekend: 9.88 (0.78)	10:38 (1.05)		<0.001
		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 <i>et al</i> , 2021, USA ⁷⁶	Actigraphy data together with daily sleep diary (for validation)	24-hour sleep duration (minutes) Sleep efficiency (%)	628.6 (29.4) 84.9 (4.6)	631.6 (30.7) 85.4 (4.5)		0.631 0.365
López-Bueno <i>et al</i> , 2020, Spain ³	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 <i>et al</i> , 2021, Netherlands ⁸³	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

Continued

Table 4 Continued

Reported outcome						
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown)	P value
Luszczki <i>et al</i> , 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
		Weekends sleep duration (hours)	10.11 (1.45)	9.52 (1.36)		<0.001
		Sleep quality (Score, higher score indicates better quality)	1.70 (0.68)	1.78 (0.65)		0.032
Masi <i>et al</i> , 2021, Australia ⁹²	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 <i>et al</i> , 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
		Weekend days sleep duration (hours/day)	9.40 (1.10)	10.10 (1.60)		<0.001
Mitra <i>et al</i> , 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) Change in sleep quality from before to during the lockdown (range: 1–5, 1 = a lot worse, 3 = no change, 5 = a lot better)			Children: 3.21 (0.70) Youth: 3.63 (0.84) Children: 3.05 (0.66) Youth: 3.04 (0.73)	

Continued

Table 4 Continued

Reported outcome						
Study	Measurement tool	Indicator	Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown)	P value
Morgül <i>et al</i> , 2020, UK ⁵⁴	Family daily routines and children's emotional and behavioural symptoms questionnaire developed by Orgilés <i>et al</i>	Sleep duration (hours/day)	9.93 (1.45)	9.55 (1.76)		<0.01
Munasinghe <i>et al</i> , 2020, Australia ⁵⁵	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 ²⁰	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 <i>et al</i> , 2021, Multi-country ²⁶	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) Bedtime (24 hour:min) Waketime (24 hour:min) % With poor sleep quality	664.7 (2.9) 21:20 (0:02) 7:09 (0:02) 5.1 (1.0)	641.2 (3.2) 22:01 (0:03) 8:09 (0:03) 6.0 (0.9)	-9.2 (-28.9, 10.6) 0:34 (0:14, 0:54)* 0:59 (0:34, 1:23)* 0.6 (0.1, 1.5)*	0.341 0.003* <0.001* 0.267*
Pietrobelli <i>et al</i> , 2020, Italy ⁹⁴	Questionnaire which included question on sleep behaviour	Sleep time (hours/day)	8.46 (0.85)	9.11 (1.10)		0.003
Pombo <i>et al</i> , 2021, Portugal ⁵⁶	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 <i>et al</i> , 2021, Canada ⁷⁹	Questions derived from the Pittsburgh Sleep Quality Index (PSQI)	Bedtime Subjective sleep quality			Delayed Improved	<0.001 <0.01
Sá <i>et al</i> , 2021, Brazil ⁵⁸	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%	

Continued

Table 4 Continued

Study	Measurement tool	Indicator	Reported outcome		
			Before lockdown (Mean (SD))	During lockdown (Mean (SD))	During lockdown (vs before lockdown) P value
Türkoğlu <i>et al</i> , 2020, Turkey ⁹⁶	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 <i>et al</i> , 2020, China ⁶⁶	International Physical Activity Questionnaire (IPAQ)-long form	Workdays median sleep duration (hours/day) Weekends median sleep duration (hours/day)	8.00 8.50	8.10 9.00	<0.001 <0.001
Zengin <i>et al</i> , 2021, Turkey ⁶¹	Questionnaire prepared by the researchers and reviewed by specialists	% With an increased sleep time % Sleeping late % Getting up late		46.4% 56.8% 39.0%	

*Adjusted.
_T1DM, type 1 diabetes mellitus.

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 studies^{85–98} 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 6.9 hours during the lockdown.⁸⁶ Turkish children with ASD showed increased sleep problems during the lockdown (total Children's Sleep Habits Questionnaire score: 47.82 before the lockdown vs 50.80 during the lockdown, p=0.001).⁹⁶ In Italy, the proportion of children with Fragile-X Syndrome often having difficulty falling asleep increased from 6% before the lockdown to 15% during the lockdown.⁸⁹

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 than before the lockdown. The evidence for sleep duration and sleep quality was inconclusive.

DISCUSSION

Lockdown measures to contain COVID-19 spread had mostly negative consequences on the movement behaviours of children and adolescents worldwide. The majority

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.

‡Inconsistent: when $\leq 75\%$ of the studies reported the same conclusion³⁷

§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 studies³⁷

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.^{6 99} Among the countries included in this review, Spanish and Brazilian children and adolescents saw the biggest decline in physical activity.^{40 52 57 58} 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.¹⁰⁰ The lockdown restriction in Spain was stringent, and children were not allowed to go outdoors.³ Most Brazilian children were living in apartments and had limited access to outdoor space for physical activity and sports.⁵⁸ 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.^{101 102}

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.²⁰ 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.¹⁹ 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.²⁰ Similarly, the lockdown restrictions in Germany were moderate, allowing outdoor activities if done alone or with family members.¹⁹ These two studies in Western Australia and Germany tracked various forms of physical activity across different settings.^{19 20} People in Australia were encouraged to exercise during the restrictions through constant messaging by government officials.²⁰ They also had a relatively conducive household environment for active indoor and outdoor play for children.²⁰

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

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.¹⁰³ Confined children and adolescents might use electronic devices more frequently to connect with their peers via social media.¹⁰⁴ 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,^{3 52 58 68} while it was comparatively lower in countries with mild restrictions, such as Germany and Australia.^{19 20}

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.¹² 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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