THE IMPACT OF COVID–19 RESTRICTIVE MEASURES ON PHYSICAL ACTIVITY IN CHILDREN AND ADOLESCENTS: A SYSTEMATIC REVIEW

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Abstract:

The purpose of this review was to gather studies that reported on the impact of COVID-19 restrictive measures on physical activity and sedentary behavior in children and adolescents, and to present key findings. The search for articles was performed in three databases of scientific literature: PubMed, Scopus, and Web of Science. We included articles that reported a change in the amount of physical activity and/or sedentary behavior during COVID-19 restrictive measures compared to the period before them. The quality of the articles was assessed using the Newcastle-Ottawa Scale. The search returned 1391 hits, out of which 23 articles were included in the review. The studies showed that participation in physical activity predominantly decreased (in 17/23 studies) and sedentary behavior predominantly increased (in 16/17 studies). The results regarding the reduction of physical activity were the most consistent for moderate to vigorous physical activity, while the direction of change was mixed for some types of physical activity (e.g., exercise, walking). The results regarding sedentary behavior were mostly consistent in terms of increasing the total amount of sedentary behavior as well as types of sedentary behavior (e.g., watching TV, using tablets). This review showed that COVID-19 restrictive measures have further increased the issue of insufficient physical activity and excessive sedentary behavior among children and adolescents. There is a need for the development of interventions for maintaining/increasing physical activity among children and adolescents that would be suitable for the implementation during the future pandemics and other similar crisis situations.

Key words: *SARS-COV-2, movement behaviors, pupils, pandemic, epidemiology*

Introduction

Coronavirus disease 2019 (COVID-19) caused by coronavirus (Severe Acute Respiratory Syndrome Coronavirus 2 [SARS-COV-2]) originally appeared in China in December 2019, and rapidly spread around the world (Amekran & El Hangouche, 2021). The World Health Organization (WHO) declared the COVID-19 outbreak a pandemic in early March 2020 (WHO, 2020c). Due to the rapid increase in infections and confirmed deaths, restrictive measures have been taken to slow the spread of the virus. In many countries, restrictive measures included the closure of non-essential public facilities and services, and stay-at-home orders (Amekran & El Hangouche, 2021). Although such measures have importantly curbed the spread of the coronavirus, they have also affected the daily routines and health-related behaviors of the residents (Amekran & El Hangouche, 2021). By the end of March 2020, the measures were believed to have affected more than half of the world population, including 1.5 billion children and adolescents (OECD, 2020; UNESCO, 2020).

Specifically, with the closure of parks, playgrounds, recreation centers, and schools, children and adolescents were left with fewer opportunities for physical activities. Namely, studies showed that children accumulate most of their daily physical activity (PA) from active transport to school, physical education classes, organized sports activities and leisure games in parks and playgrounds, while most of the sedentary time is accumulated at home (Guan, et al., 2020). Moreover, children who spend more time outside are more physically active, less sedentary and sleep better (Tremblay, et al., 2015). Studies also showed that children are less active and spend more time using electronic devices on unstructured days when they do not go to school (e.g., summer holidays, weekends) (Brazen-

dale, et al., 2017; Wang, et al., 2019). Therefore, it is very likely that COVID-19 restrictive measures unfavorably influenced levels of PA and sedentary behavior (SB) among children and adolescents.

Physical activity plays a very important role in health and fitness of young people, and it is an essential component of healthy growth and development (Hills, King, & Armstrong, 2007). Children undergo intense motor learning in the first years of life (Hills, et al., 2007). Studies show that a lack of engagement in diverse PA in childhood can lead to developmental disorders or to the inability to develop and exploit the individual's motor skills potential in later life (Myer, et al., 2015). Engagement in PA also improves the capacity of cardio-vascular, respiratory, and musculo-skeletal systems (PAGAC, 2018; Poitras, et al., 2015). PAGAC (2018) has reported that regular aerobic PA positively affects cardio-metabolic parameters such as blood pressure, lipid profile, glucose regulation, and insulin resistance. Numerous studies report that cardio-vascular disease may originate in childhood, so early interventions are crucial (McMurray & Ondrak, 2013). PA can also help at obtaining favorable body composition and healthy body weight (PAGAC, 2018; Poitras, et al., 2015). Moreover, numerous positive effects of PA on mental health, brain function and cognitive performance have also been demonstrated. Active children and adolescents are more likely to have better academic performance (PAGAC, 2018).

However, according to the WHO, approximately 80 % of children and youth worldwide are insufficiently physically active (WHO, 2019). Many are spending most of their free time sedentary in front of computer and television screens, and do not accumulate the recommended 60 min/day of intensive PA (WHO, 2020b). Adopting an inactive lifestyle during childhood or adolescence is also a predictor of PA participation in adulthood (Dohle & Wansink, 2013; Telama, et al., 2005). The COVID-19 outbreak and the restrictive measures that followed have potentially worsened the issue of insufficient PA and excessive SB in children and youth.

Therefore, the purpose of the present study was to review recently published findings about the impact of COVID-19 restrictive measures on PA and SB in children and adolescents. Our hypothesis was that during the COVID-19 restrictive measures, children and adolescents decreased their PA participation and increased their time spent in SB.

Methods

The systematic review was carried out following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati, et al., 2009).

Search strategy

The search for articles was performed in three databases of scientific literature: PubMed, Scopus, and Web of Science (in February 2021). The search character chain was designed with a combination of the keywords *sars-cov-2, covid-19* and *physical activity, physical inactivity, sedentary behavior, sedentary behaviour, sedentary lifestyle*, connected with the logical operator OR and AND. Keywords were searched in the title, abstract, and keyword fields.

All hits from the three databases of the scientific literature were transferred to the Mendeley Desktop Reference Management Program. We removed the duplicates first. Then two authors (TP and KK) independently reviewed the titles and abstracts of the articles. The third author (NŠ) participated in resolving any discrepancies between the two authors. We obtained full texts of potentially relevant articles and two authors (TP and KK) independently reviewed them for eligibility.

Inclusion and exclusion criteria

We included studies that reported a change in the amount of PA and/or SB among children and adolescents (i.e., studies that compared the period before and during the COVID-19 restrictive measures). We included studies that examined the cumulative amount of daily PA of various intensities and/or SB, as well as those examining different types of PA and/or SB (e.g., exercise, number of steps per day, screen time). We only included cross-sectional and longitudinal studies that were published in peer-reviewed English language journals. Studies performed on specific subpopulations such as patients, people with physical or mental disabilities and top athletes were excluded.

Data extraction

Data from the included studies were extracted by two authors (TP and KK). The third author (NŠ) participated in resolving any discrepancies between the two authors. We extracted the following data: first author, country, type of study, data collection time, sample (sample size, age, sex), tool for PA and SB assessment, restrictive measures, amount of PA and SB before COVID-19 restrictive measures, amount of PA and SB during COVID-19 restrictive measures, and the reported change in PA and SB. In case of insufficient or unclear information, we contacted the authors of the study.

Evaluation of studies

The quality of the articles was assessed using the Newcastle-Ottawa scale (NOS) for cohort studies (Wells, et al., 2013) (to assess cohort studies) and an adapted NOS for cross-sectional studies (Herzog, et al., 2013) (to assess cross-sectional studies). Two

authors independently evaluated the studies (TP and KK) and the third author (NŠ) participated in resolving possible discrepancies between the two authors.

The Newcastle-Ottawa scale is a quality assessment tool for studies, which uses a star rating system to evaluate studies according to three domains: selection of study groups, comparability, and outcome. These domains are further divided into a total of seven (for cohort studies) or eight (for cross-sectional studies) items. When the requirements of an individual item are met, one or two stars are awarded to the study. The maximum possible rating is 10 stars. NOS assessments are divided into three groups: good-quality (7-10 points), medium-quality (5-6 points), and poor-quality studies (0-4 points) (Herzog, et al., 2013; Modesti, et al., 2016).

Results

Our search returned 1391 hits. After removing the duplicates, we reviewed the titles and abstracts of 1271 articles. During the review, we excluded all content-inappropriate articles or articles that did not focus on the change in PA and/or SB due to the COVID-19 pandemic, and articles that did not cover the population of generally healthy children and adolescents. In the end, 23 articles were included in the review (Figure 1). All included studies reported changes in PA (Supplementary Table 1) and 17 studies also reported changes in SB (Supplementary Table 2). In 21 studies, PA and/or SB were evaluated using self-reported questionnaires (out of which 15 studies used unvalidated questionnaires), while two studies used device-based estimates (Alonso-Martínez, Ramírez-Vélez, García-Alonso, Izquierdo, & García-Hermoso, 2021; Munasinghe, et al., 2020). The average score of the quality of studies according to the NOS scale was 6.0 (SD = 0.7). Four studies were rated as good, 18 as medium, and one as poor quality.

Changes in intensity-specific PA

The effect of COVID-19 restrictive measures on total PA was reported in four studies. Three studies included pre-school children aged 1-5 years, and one study included children aged 5-13 years. During the restrictive measures, PA was reported to decrease by 43 min/day (Alonso-Martínez, et al., 2021) and 47 min/day (Aguilar-Farias, et al., 2020), or to increase by 53 min/day (Nyström, et al., 2020). One study reported that PA level declined in 54 % of children aged 5-8 years, and in 67 % of children aged 9-13 years (Dunton, Do, & Wang, 2020).

The impact of the pandemic on the total amount of moderate to vigorous physical activity (MVPA) has been observed in 12 studies (Alonso-Martínez, et al., 2021; Elnaggar, Alqahtan, Mahmoud, & Elfakharany, 2020; Francisco, et al., 2020; Gilic, Ostojic, Corluka, Volaric, & Sekulic, 2020; López-Bueno, et al., 2020; Medrano, et al., 2020; Morgül, Kallitsoglou, & Essau, 2020; Ng, Cooper, McHale, Clifford, & Woods, 2020; Tornaghi, Lovecchio, Vandoni, Chirico, & Codelha, 2020; Xiang, Zhang, & Kuwahara, 2020; Yang, et al., 2020; Zenic, et al., 2020). Decreased levels of MVPA have been reported by all but two studies (Tornaghi, et al.,

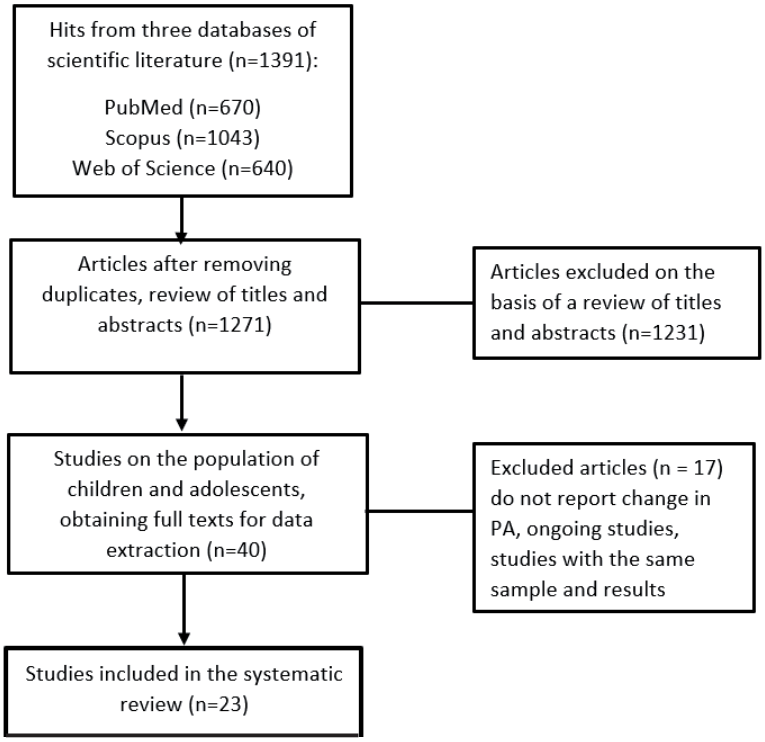

Figure 1. Flow chart of stages of article selection.

Supplementary Table 1. Changes in physical activity during COVID-19 among children and adolescents

Author, country	Study type, time of data collection	Sample	PA assessment tool	Restrictive measures	PA before the COVID-19 pandemic	PA during the COVID-19 pandemic	Change in PA
Aguilar-Farias et al. (2020), Chile	Cross-sectional, 30 March to 27 April 2020, beginning 2 weeks after school centers closed, still closed at the end of the data collection	n = 3157 toddlers and pre-school children (1597 boys), 1-5 years, average age: 3.1 years	Online questionnaire; "On a typical day before/after the closure of educational centers, how long did your child spent doing PA, considering all he did during the day?"	March 16: all schools closed, work from home strategies in the same week; 17 March: all parks closed; 26 March: lockdowns and curfews in some districts	TPA: 3.6 (1.97) h/day Children 1 year: 3.94 (2.17) h/day Children 5 years: 3.23 (1.62) h/day	TPA: 2.82 (2.15) h/day Children 1 year: 3.65 (2.42) h/day Children 5 years: 2.25 (1.81) h/day	TPA: –0.78 h/day Children 1 year: –0.29 h/day Children 5 years: –0.98 h/day
Alonso-Martínez et al. (2021), Spain	Longitudinal, first assessment: September to December 2019, second assessment: March to April 2020	n = 21 pre-school children (12 boys), 4-6 years, average age: 4.29 years	Tri-axial accelerometer GENEActiv	Mandatory home lockdown from 14 March to 26 April 2020	MVPA: 91.6 (26.7) min/day TPA: 346.9 (54.6) min/day	MVPA: 74.6 (26.0) min/day TPA: 303.6 (76.5) min/day	MVPA: –17 min/day TPA: –43,3 min/day
Carroll et al. (2020), Canada	Cross-sectional, 20 April to 15 May 2020	n = 310 children 18 months to 5 years, average age: 5.7 years	Online questionnaire	Not reported			PA (active play and time spent outside): –: 51% +: 10% NC: 39%
dos Santos Cardoso de Sá et al. (2020), Brazil	Cross-sectional, 24 March 2020	n = 816 pre-school children and children (410 boys), 0-12 years	Online questionnaire *	Mid-March: closed schools, isolation from 25 March to 24 April 2020			Active play (hide and seek, run and catch, jumping rope…) and PA (organized PA indoors/ outdoors, walking the dog): –: 83.1% +: 5.1% NC: 11,9 %
Dragun et al. (2020), Croatia	Cross-sectional, before Covid assessment: April/ May 2018 and April/May 2019, during Covid assessment: May 2020, immediately after the beginning of the easing of measures	2018 and 2019 sample: n = 769 students (294 boys), average age: 17.0 years; of which the sample studied: n = 388, 2020 sample: n = 324 students (92 boys), average age: 17.5 years	2018 and 2019 sample: questionnaire, paper and pencil format 2020 sample: online questionnaire	One of the countries with the strictest restrictive measures; the first measures established on 9 March 2020; 16 March 2020: Schools swiched to online classes; a few days later closed restaurants, cinemas, gyms, shopping malls etc.; 23 March 2020: complete lockdown, free movement around the country without permission is restricted; 27 May 2020: easing of restrictive measures, schools (except for the youngest) closed until the end of the school year in June	PA (sports, gym, recreation) participation: Weekly (active several times a week): 60.8% Sometimes: 13.1% Rarely/never: 26.0%	PA (sports, gym, recreation) participation: Weekly (active several times a week): 66.7% Sometimes: 15.4% Rarely/never: 17.9%	
Dunton et al. (2020), USA (35 states and the District of Columbia)	Cross-sectional, 25 April to 16 May 2020	n = 211 children (99 boys), 5-13 years, average age: 8.71 years	Online questionnaire; "How physically active has your child been in the last seven days compared to February 2020?", responses on a 5-point scale	Mid-March: primary and secondary schools closed (many remain closed until the end of the 2019/2020 school year); through May: canceled sports activities, clubs in most countries; second half of March: many parks, playgrounds, trails and beaches closed (with a few openings in April and May)			PA (5-8 years): –: 54% +: 29% NC: 16% PA (9-13 years): –: 67% +: 13% NC: 19%
Elnaggar et al. (2020), Egypt, Saudi Arabia	Longitudinal	n = 63 adolescents (34 boys), 14-18 years, average age: 15.54 years	PAQ-A*, Online questionnaire	Not reported	PA level: 3.05 (0.54) Boys: 3.20 (0.57) Girls: 2.87 (0.45)	PA level: 2.77 (0.47) Boys: 2.76 (0.49) Girls: 2.79 (0.44)	PA level: –0.28 Boys: -0.44 Girls: -0.08

Author, country	Study type, time of data collection	Sample	PA assessment tool	Restrictive measures	PA before the COVID-19 pandemic	PA during the COVID-19 pandemic	Change in PA
Francisco et al. (2020), Italy, Spain, Portugal	Cross-sectional, March to April 2020, early period of quarantine	n = 1480 children and adolescents (781 boys), 3-18 years, average age: 9.15 years	Online questionnaire; "During quarantine, how much time did your child spend daily on PA?", 6 options to respond	Italy closes schools on 5 March 2020 (24 February Lombardy); Spain and Portugal on 13 March 2020 Italy and Spain enforce mandatory quarantine; Portugal voluntary quarantine	Daily PA: <30 min/day: 12.8% 30-60 min/day: 33.1% 60-90 min/day: 28.1% 90-120 min/day: 13.4% 120-180 min/day: 6.9% > 180 min/day: 5.7%	Daily PA: <30 min/day: 53% 30-60 min/day: 32.2% 60-90 min/day: 9.3% 90-120 min/day: 3.4% 120-180 min/day: 1.1% > 180 min/day: 1%	Daily PA: <30 min/day: + 40.2% 30-60 min/day: -0.9% 60–90 min/day: –18.8% 90–120 min/day: –10% 120–180 min/day: –5.8% > 180 min/day: –4.7%
Gilic et al. (2020), Bosnia and Herzegovina	Longitudinal, first assessment: January 2020, second assessment: April 2020	n = 688 adolescents (366 boys), 15-18 years, average age: 17 years	PAQ-A* (paper and pencil, online format)	Social distancing, closed schools, sports clubs, fitness centers, shopping malls, no group gatherings	PA level: 2.98 (0.71) Boys: 3.12 (0.56) Girls: 2.69 (0.49) Meeting recommendations: 50%	PA level: 2.31 (0.68) Boys: 2.50 (0.44) Girls: 1.95 (0.56) Meetin recommendations: 24%	PA level: –0.67 Boys: –0.62 Girls: –0.74 Meeting recommendations: –26%
López-Bueno et al. (2020), Spain	Cross-sectional, March 22-10 May 2020	n = 860, preschool children, children, adolescents (437 boys), 3-16 years, average age: 9.6 years	Online questionnaire: "How many minutes of physical activity does your child usually perform on a weekly basis?"	Strict restrictive period (15 March-25 April 2020): free movement of minors (except for medical reasons) banned; subjects aged 15 years or over can go out once a day (dog walking, shopping ...), maintaining distance; April 25: subjects under 14 years of age can go out for a maximum of 1 hour a day accompanied by parents, curfew; after May 2: activity outside is allowed only at specific hours	MVPA: 198.6 (180.9) min/week	MVPA: 96.1 (123.0) min/week	MVPA: –102.5 (159.6) min/week
McCormack et al. (2020), Canada	Cross-sectional, 14 April to 27 May 2020	n=328, children and adolescents (189 boys), 5-17 years, average age: 10.8 years	Online questionnaire	Closure of schools and kindergartens, non-essential companies, recreational facilities (playgrounds, sports fields ...); recommended social isolation and distance maintenance			PA at home –: 18.3% +: 48.8% NC: 32.9% PA outside –: 39.0% +: 38.7% NC: 22,3% Playing at park: –: 52.7% +: 15.5% NC: 31.7% Playing at other public places: –: 53.7% +: 9.5% NC: 36.9% Time spent outside with friends: –: 70.7% +: 5.8% NC: 23.5%
Medrano et al. (2020), Spain	Longitudinal, first assessment: September to December 2019, second assessment: March to April 2020	n = 113 children and adolescents (58 boys), 8-16 years, average age: 12 years	YAP, online	14 March, 2020, the beginning of measures: mandatory quarantine, school closure, children were not allowed to leave the house for 6 weeks	MVPA: 154 (40) min/day	MVPA: 63 (39) min/day	MVPA: –91 (55) min/day PA: –: 95.2%

Author, country	Study type, time of data collection	Sample	PA assessment tool	Restrictive measures	PA before the COVID-19 pandemic	PA during the COVID-19 pandemic	Change in PA
Mitra et al. (2020), Canada	Cross-sectional, April 2020, one month after the pandemic is declared	n = 1472, children and adolescents (697 boys), 5-17 years, 53% (5-11 years) 47% (12-17 years)	Online questionnaire: "Compared to the period before the COVID-19 pandemic, my child is doing household chores (cleaning, yard work ...)?", responses on a 5-point scale	Keeping distance, socializing banned, sporting events banned, closed parks and playgrounds in some places, most schools closed		Walk or bike: –: 53.2% +: 20.5% NC: 26.3% Sports/PA outside: –: 63.8% +: 14% NC: 22.2% Playing inside: –: 7% +: 53.1% NC: 39.9%	Household chores –: 8.2% +: 37.9% NC: 53.9% Sports/PA inside: –: 34% +: 25.5% NC: 40.5% Playing outside: –: 51.2% +: 17.9% NC: 30.9%
Morgül et al. (2020), United Kingdom	Cross-sectional, 4 July to 14 August 2020	n = 927, children (505 boys) 5-11 years, average age: 7.45 years	Online questionnaire: "During quarantine, how much time did your child spend per day on PA?", 6 options to respond	Not reported	Daily PA: <30 min/day: 3.7% 30–60 min/day: 29% 60–90 min/day: 30.2% 90–120 min/day: 20.3% 120–180 min/day: 6.7% >180 min/day: 10.1%	Daily PA: <30 min/day: 16.2% 30–60 min/day: 32.7% 60–90 min/day: 25.1% 90–120 min/day: 13.5% 120–180 min/day: 6.7% >180 min/day: 5.8%	Daily PA: <30 min/day: +12.5% 30–60 min/day: +3.7% 60–90 min/day: –5.1% 90–120 min/day: –6.8% 120–180 min/day: +0% >180 min/day: –4.3%
Munasinghe et al. (2020), Australia	Longitudinal, 18 November 2019 to 19 April 2020	n = 515, adolescents (92 boys), 16-18 years, average age: 17 years	Mobile application »Ethica Data«	23 March 2020: enforcement of restrictive measures	Number of steps: 2700 steps/day Walking: 75 min/day 60 min MVPA per day: 48.61%	Number of steps: 1700 steps/day Walking: 55 min/day 60 min MVPA per day: 43.64%	Number of steps: –1000 steps/day Walking: –20 min/day 60 min MVPA per day: –4.97%
Ng et al. (2020), Ireland	Cross-sectional, April 2020	n = 1214 adolescents (367 boys), 12-18 years	PACE +, online format: "Has the amount of PA done in the last seven days been the same as the amount you normally do?"	Not reported			MVPA: –: 49.7% +: 19.1% NC: 31.2%
Nyström et al. (2020), Sweden	Longitudinal, first assessment: March to May 2019, second assessment: May to June 2020	n = 100 preschool children (58 boys), 3-5 years, average age: 4 years	First time: paper questionnaire; second time COVID-19 questionnaire over the phone	Kindergartens, playgrounds and parks remained open; organized sports activities for children continue, kindergartens change routines (children spend more time outside)	TPA: 209 (119) min/day Time spent outside weekdays: 196 (85) min/day Time spent outside weekend days: 191 (82) min/day	TPA: 262 (123) min/day Time spent outside weekdays: 320 (112) min/day Time spent outside weekend days: 259 (96) min/day	TPA: +53 min/day Time spent outside weekdays: +124 min/day Time spent outside weekend days: +68 min/day
Ruíz-Roso et al. (2020), Italy, Spain, Brazil, Chile, Colombia	Cross-sectional, 17 April to 20 May 2020	n = 726 adolescents, (293 boys), 16-19 years old	IPAQ*, online	In all countries, start of measures in March 2020. Chile: only in Chile no lockdown, mandatory quarantine in some places, school closure on 16 March 2020	Active: 27.0% Brazil: 59.1% Chile: 20% Colombia: 27.3% Spain: 21.1% Italy: 14.3%	Active: 20.5% Brazil: 7% Chile: 9.4% Colombia: 29.2% Spain: 29.3% Italy: 26.3%	Active: –6.5% Brazil: -52.1% Chile: -10.6% Colombia: +1.9% Spain: +8.2% Italy: +12%

Author, country	Study type, time of data collection	Sample	PA assessment tool	Restrictive measures	PA before the COVID-19 pandemic	PA during the COVID-19 pandemic	Change in PA
Schmidt et al. (2020), Germany	Longitudinal, first assessment: August 2018, second assessment: 20 April to 1 May 2020	n = 1711, children and adolescents (859 boys), 4-17 years, average age: 11.34 years	MOMO-PAQ* (paper/ online format)	16–18 March 2020: closed kindergartens, schools, sports clubs, gyms and other institutions related to PA, maintaining distance, no more than 2 people from different households. Non-organized sports and outdoor PA allowed. The closure lasts until 3 May 2020	Total amount of sports: 34.9 (26.0) min/ day Playing outside: 56.9 (58.2) min/ day Walking and cycling: 39.2 (26.0) min/ day Gardening: 6.9 (19.9) min/day Housework: 7.8 (14.7) min/day Days active: 4.3 (1.8) days/ week Total habitual PA: 107.3 (73.9) min/day PA guideline adherence: 19.1% (4-5 years): 31.0% (14-17 years): 5.8%	Total amount of sports: 24.3 (36.2) min/day Playing outside: 78.3 (88.8) min/day Walking and cycling: 41.0 (30.3) min/day Gardening: 13.6 (3.0) min/day Housework: 11.8 (18.5) min/day Days active: 4.7 (2.0) days/week Total habitual PA: 143.5 (110.5) min/day PA guideline adherence: 30.2% (4-5 years): 45.7% (14-17 years): 10.4%	Total amount of sports: –10.8 min/day Playing outside: +21.4 min/day Walking and cycling: +1.8 min/day Gardening: +6.7 min/day Housework: +4 min/day Days active: +0.4 days/week Total habitual PA: +35.2 min/day PA guideline adherence: +11.1% (4-5 years): +14.7% (14-17 years): +4.8%
Tornaghi et al. (2020), Italy	Longitudinal, First assessment: 27 to 31 January 2020, second assessment: 4 to 10 April 2020	n = 1568 adolescents, 15-18 years	IPAQ short form*, online format	11 March and 22 March 2020: initially limited and then abrogated nonessential movements (including sports), only activities within 200 m of the range from home allowed while maintaining distance	MVPA: 1676.37 (20.6) MET-min/week Highly active individuals: 3151.43 (42.41) MET-min/week Meeting recommendations: 6.8%	MVPA: 1730 MET-min/week Highly active individuals: 3467.48 (55.85) MET-min/week Meeting recom-mendations: 14.7%	
Zenic et al. (2020), Croatia	Longitudinal, first assessment: October 2019 to March 2020, second assessment: April 2020	n = 823 adolescents, average age: 16.5 years	PAQ-A*, online format	Mid-March 2020: closed schools and universities; 19 March 2020: group gatherings banned, closure of restaurants, shopping malls, sports and fitness centers, theaters, cinemas, churches; only the most essential shops remain open; maintaining distance; second data collection: closed playgrounds, parks; outdoor exercise allowed	PA level: 2.97 (0.61)	PA level: 2.63 (0.68)	PA level: –0.34
Xiang et al. (2020), China	Longitudinal, first assessment: 3 to 21 January 2020, second assessment: 13 to 23 March 2020	n = 2426 children and adolescents (1242 boys), 6-17 years	GPAQ*, online format	Not reported	PA (MPA + 2 * VPA): 540 min/ week Sufficient PA: 60%	PA: 105 min/week Sufficient PA: 17.7%	PA: –435 min/week Sufficient PA: –42.3%

Author, country	Study type, time of data collection	Sample	PA assessment tool	Restrictive measures	PA before the COVID-19 pandemic	PA during the COVID-19 pandemic	Change in PA
Yang et al. (2020), China	Cross-sectional, May 2020 (subjects respond for pre-pandemic and pandemic periods)	n = 2824 high school students (678 boys), average age: 17.5 years	IPAQ, online format		Active transport: 1.5 (1.0, 2.2) h/day	Active transport: (0.5, 1.8) h/day	Active transport: -: 20.3% +: 2.3% NS: 77.4%
					Housework: 2.0 (1.3, 3.3) h/day	Housework: 2.3 (1.5, 4.0) h/day	Housework: -: 39.1% +: 10.8% NC: 50.1%
					Leisure MVPA: 1.5 (1.0, 2.5) h/day	Leisure MVPA: 1.5 (1.0, 2.8) h/day	Leisure MVPA: -: 16.1% +: 3.5% NC: 80.4%
					Leisure walking: 1.0 (0.7.1.5) h/day	Leisure walking: 1.0 (0.5,1.5) h/day	Leisure walking: -: 18.2% +: 1.9% NC: 79.9%

Note. PA = physical activity, + = increase, - = decrease; NC = no change, MET = metabolic equivalent, TPA = total physical activity, MVPA = moderate to vigorous physical activity, MPA = moderate physical activity, VPA = vigorous physical activity, MOMO-PAQ = MoMo Physical Activity Questionnaire, IPAQ = International Physical Activity Questionnaire, GPAQ = Global Physical Activity Questionnaire, PACE + = PACE + Questionnaire, PAQ-A = Physical Activity Questionnaire for Adolescents, COVID-19 = Coronavirus Disease 2019, * = Validated questionnaires.

Supplementary Table 2. Changes in sedentary behavior during COVID-19 among children and adolescents

Author, country	Study type, time of data collection	Sample	SB assessment tool	Restrictive measures	SB before the COVID-19 pandemic	SB during the COVID-19 pandemic	Change in SB
Aguilar-Farias et al. (2020), Chile	Cross-sectional, 30 March to 27 April 2020 (beginning 2 weeks after the closure of school centers, still closed at the end of the collection)	n = 3157 toddlers and pre-school children (1597 boys), 1-5 years, average age: 3.1 years	Online questionnaire: "On a normal day, before/after the closure of educational centers, for how much time in total do you estimate the child spent using screen devices such as a smartphone or tablet, playing video games, watching TV, movies, or videos over the Internet while sitting or lying down? "	16 March 2020: all schools closed, work from home strategies in the same week; 17 March 2020: all parks closed; 26 March 2020: lockdowns and curfews in some districts	Screen time: 1.66 (1.15) h/day	Screen time: 3.05 (1.92) h/day	Screen time: +1.39 h/day
Alonso-Martínez et al. (2021), Spain	Longitudinal, first assessment: September to December 2019, second assessment: March to April 2020	n = 21 preschool children (12 boys) 4-6 years, average age: 4.29 years	Tri-axial accelerometer GENEActiv	Mandatory home lockdown from 14 March to 26 April 2020	Total SB: 609.6 (69.4) min/day	Total SB: 659.8 (116.6) min/day	Total SB: +50.2 min/day
Carroll et al. (2020), Canada	Cross-sectional, 20 April to 15 May 2020	n = 310 children 18 months to 5 years, average age: 5.7 years	Online questionnaire	Not reported			Screen time: +: 87 % –: 0.5 % NC: 12.5 %
dos Santos Cardoso de Sá et al. (2020), Brazil	Cross-sectional, 24 March 2020	n = 816 preschool children and children (410 boys), 0-12 years	Online questionnaire *	Mid-March: closed schools, isolation from 25 March to 24 April 2020			Screen time: +: 74.9 % –: 8 % NC: 17.2 %

Author, country	Study type, time of data collection	Sample	SB assessment tool	Restrictive measures	SB before the COVID-19 pandemic	SB during the COVID-19 pandemic	Change in SB
Dragun et al. (2020), Croatia	Cross-sectional, before Covid assessment: April/ May 2018 and April/May 2019, during Covid assessment: May 2020, immediately after the beginning of the easing of measures	2018 and 2019 sample: n = 769 students (294 boys), average age: 17.0 years; of which the sample studied: n = 388, 2020 sample: n = 324 students (92 boys), average age: 17.5 years	Questionnaire, pen and paper format Online questionnaire	One of the countries with the strictest restrictive measures; the first measures established on 9 March 2020; 16 March 2020: Schools swiched to online classes; a few days later closed restaurants, cinemas, gyms, shopping malls; 23 March 2020, complete lockdown, free movement around the country without permission is restricted; 27 March 2020 easing of restrictive measures, schools (except for the youngest) closed until the end of the school year in June	Sitting time: 7.5 (4.0) h/day TV: 1.0 (1.8) h/day Computer & tablet: 0.5 (1.0) h/day Mobile phone: 3.5 (2.5) h/day	Sitting time: 5.0 (5.0) h/day TV: 1.0 (1.7) h/day Computer & tablet: 3.0 (3.5) h/day Mobile phone: 4.0 (3.2) h/day	Sitting time: –2.5 h/day TV: + 0 h/day Computer & tablet: + 2.5 h/day Mobile phone: 0.5 h/day TV: +: 16,4 % –: 1.9 % NC: 69,8 % Computer & tablet: +: 78.4% –: 3.7% NC: 17.9% Mobile phone: +: 68.2% –: 4.0% NC: 27.8%
Dunton et al. (2020), USA (35 states and the District of Columbia)	Cross-sectional, 25 April to 16 May 2020	n = 211 children (99 boys), 5-13 years, average age: 8.71 years	Online questionnaire: "How much sitting has your child been doing in the last seven days, compared to February 2020?"	Mid-March 2020: primary and secondary schools closed (many remain closed until the end of the 2019/2020 school year); through May 2020: canceled sports activities, clubs in most countries; second half of March: many parks, playgrounds, trails and beaches closed (with a few openings in April and May)			SB (5–8 years): –: 22 % +: 63 % NC: 15 % SB (9–13 years): –: 7 % +: 83 % NC : 10 %
Francisco et al. (2020), Italy, Spain, Portugal	Cross-sectional, March to April 2020, early period of quarantine	n = 1480 adolescent children (781 boys), 3-18 years, average age: 9.15 years	Online questionnaire: "Before quarantine, how long did your child spend in front of screens such as tablets, televisions, cell phones and computers daily?"	Italy closes schools on 5 March 2020 (24 February for Lombardy); Spain and Portugal on 13 March 2020 Italy and Spain enforce mandatory quarantine; Portugal voluntary quarantine	Screen time, daily: <30 min/day: 20.7% 30-60 min/day: 35.7% 60-90 min/day: 23.4% 90-120 min/day: 11% 120-180 min/day: 5.7% > 180 min/day: 3.5%	Screen time, daily: <30 min/day: 3% 30-60 min/day: 10.7% 60-90 min/day: 16.7% 90-120 min/day: 20.7% 120-180 min/day: 18.8% > 180 min/day: 30.1%	Screen time, daily: <30 min/day: –17.7% 30-60 min/day: –25% 60–90 min/day: –6.7% 90–120 min/day: + 9.7% 120–180 min/day: +13.1% > 180 min/day: +26.6%
López-Bueno et al. (2020), Spain	Cross-sectional, 22 March to 10 May 2020	n = 860 preschool children, children and adolescents (437 boys), 3-16 years, average age: 9.6 years	Online questionnaire: "How many hours a day is your child exposed to screen devices such as television, cell phone, tablet?"	Strict restrictive period (15 March to 25 April 2020): free movement of minors (except for medical reasons) banned; subjects aged 15 years or over can go out once a day (dog walking, shopping ...), maintaining distance; 25 April 2020: subjects under 14 years of age can go out for a maximum of 1 hour a day accompanied by parents, curfew; after 2 May 2020: activity outside is allowed only at specific hours	Screen time: 2.0 (1.6) h/day	Screen time: 4.9 (2.3) h/day	Screen time: +2.9 (2.1) h/day

Author, country	Study type, time of data collection	Sample	SB assessment tool	Restrictive measures	SB before the COVID-19 pandemic	SB during the COVID-19 pandemic	Change in SB
McCormack et al. (2020), Canada	Cross-sectional, 14 April to 27 May 2020	n = 328 children and adolescents (189 boys), 5-17 years, average age: 10.8 years, 80.5% (5-11 years)	Online questionnaire	Closure of schools and kindergartens, non-essential companies, recreational facilities (playgrounds, sports fields, etc.); recommended social isolation and distance maintenance		Screen time (withouth watching television and playing video games) +: 75.9% –: 2.1% NC: 22.0%	Watching television +: 58.8% –: 2.7% NC: 38.4% Playing video games +: 56.4% –: 2.7% NC: 40.9%
Medrano et al. (2020), Spain	Longitudinal, first assessment: September to December 2019, second assessment: March to April 2020	n = 113 children and adolescents (58 boys), 8-16 years, average age: 12 years	YAP, online format	14 March 2020: the beginning of measures: mandatory quarantine, school closure; children were not allowed to leave the house for 6 weeks	Screen time: 4.3 (2.4) h/day TV more than or equal to 2 h/day: 2.8% Video games more than or equal to 2 h/day: 5.7% Computer (without homework) more than or equal to 2 h/day: 0.9% Telephone more than or equal to 2 h/day: 3.8%	Screen time: 6.1 (2.4) h/day TV more than or equal to 2 h/day: 13.2% Video games more than or equal to 2 h/day: 6.6% Computer (without homework) more than or equal to 2 h/day: 0.0% Phone more than or equal to 2 h/day: 18.9%	Screen time: +1.8 h/day TV more than or equal to 2 h/day: +10.4% Video games more than or equal to 2 h/day: +0.9% Computer (without homework) more than or equal to 2 h/day: –0.9% Telephone more than or equal to 2 h/day: +15.1% Screen time: +69,8 %
Mitra et al. (2020), Canada	Cross-sectional, April 2020, one month after the pandemic was declared	n = 1472 children and adolescents (697 boys) 5-17 years, 53% (5-11 years), 47% (12-17 years)	Online questionnaire: "Compared to the period before the COVID-19 pandemic, my child watches television, movies, uses the computer for leisure or plays sedentary video games?", responses on a 5-point scale	Keeping distance, socializing banned, sporting events banned, closed parks and playgrounds in some places, most schools closed			Screen time: +: 78.8% –: 3.7% NC: 17.5% Social media use: +: 44.6% –: 5.3% NC: 50.1%
Morgül et al. (2020), United Kingdom	Cross-sectional, 14 July to 14 August 2020	n = 927 children (505 boys), 5-11 years, average age: 7.45 years	Online questionnaire: "Before quarantine, how long did your child spend in front of screens such as tablets, televisions, cell phones and computers?"		Screen time daily: <30 min/day: 13.4% 30–60 min/day: 38.0% 60–90 min/day: 32.3% 90–120 min/day: 12.1% 120–180 min/day: 2.9% >180 min/day: 1.4%	Screen time daily: <30 min/day: 1.6% 30–60 min/day: 6.3% 60–90 min/day: 12.1% 90–120 min/day: 21.7% 120–180 min/day: 24.6% >180 min/day: 33.8%	Screen time daily: <30 min/day: –11.8% 30–60 min/day: –31.7% 60–90 min/day: –20.2% 90–120 min/day: +9.6% 120–180 min/day: +21.7% >180 min/day: +32.4%
Munasinghe et al. (2020), Australia	Longitudinal, 18 November 2019 to 19 April 2020	n = 128 adolescents (23 boys), 16-18 years old, average age: 17 years	Modified ASAQ, online format; mobile application "Ethica Data"	23 March 2020: Enforcement of restrictive measures	Internet, social media, playing video games: 3 hours or less: 58.7% 4 hours or more: 41.3% Mobile phone: 4.25 h/day	Internet, social media, playing video games: 3 hours or less: 55.76% 4 hours or more: 44.24% Mobile phone: 5.25 h/day	Mobile phone: +1 h/day

Author, country	Study type, time of data collection	Sample	SB assessment tool	Restrictive measures	SB before the COVID-19 pandemic	SB during the COVID-19 pandemic	Change in SB
Nyström et al. (2020), Sweden	Longitudinal, first assessment: March to May 2019, second assessment: May to June 2020	n = 100 pre-school children, (58 boys), 3-5 years, average age: 4 years	First time paper form; Second time COVID-19 questionnaire by phone: "In the 24 hours in the past week (the day your child was not in childcare/preschool and you were not at work), how much time did your child spend using screen devices such as a smartphone or tablet or spend playing video games, watching TV, movies, videos while sitting or lying down? "	Kindergartens, playgrounds and parks remained open; organized sports activities for children continue, kindergartens change routines (children spend more time outside)	Screen time: 106 (71) min/day	Screen time: 136 (78) min/day	Screen time: +30 min/ day
Schmidt et al. (2020), Germany	Longitudinal first assessment: August 2018, second assessment: 20 April to 1 May 2020	n = 1711 children and adolescents (859 boys), 4-17 years, average age: 11.34 years	MOMO-PAQ* (paper/ online format)	16–18 March 2020: closed kindergartens, schools, sports clubs, gyms and other institutions related to PA, maintaining distance, no more than 2 people from different households. Non-organized sports and outdoor PA allowed. The closure lasts until 3 May 2020	TV: 46.2 (43.5) min/ day Playing video games: 37.0 (54.9) min/day Recreational internet: 51.1 (66.8) min/day Screen time: 133.3 (123.1) min/day	TV: 67.4 (56.2) min/day Playing video games: 58.5 (68.9) min/day Recreational internet: 69.6 (73.0) min/day Screen time: 194.5 (141.3) min/day	TV: +21.2 min/day Playing video games: +21.5 min/day Recreational internet: +18.5 min/day Screen time: +61.2 min/day
Xiang et al. (2020), China	Longitudinal, First assessment: 3 to 21 January 2020, Second assessment: 13 to 23 March 2020	n = 2426 children and adolescents (1242 boys), 6-17 years	GPAQ*, online format	Not reported	Screen time: 610 min/week	Screen time: 2340 min/week	Screen time: +1730 min/week
Yang et al. (2020), China	Cross-sectional, May 2020	n = 2824 high school students (678 boys), average age: 17.5 years	IPAQ, online format	Not reported	Screen time (TV, computer): 4.0 (3.0, 6.0) h/day SB during workdays: 3.5 (2.0, 5.5) h/day SB during weekends: 3.3 (2.0, 6.2) h/day	Screen time (TV, computer): 5.0 (4.0, 6.0) h/day SB during workdays: 4.0 (2.0, 6.5) h/day SB during weekends: 4.0 (2.0, 6.2) h/day	Screen time (TV, computer): +: 29.9% -: 8.3% NC: 61.8% SB during workdays: +: 36.4% -: 25.0% NC: 38.6% SB during weekends: +: 37.4% -: 22.1% NC: 40.5%

Note. SB = sedentary behavior, + = increase, - = decrease; NC = no change, TV = television viewing, COVID-19 = coronavirus disease 2019, MOMO-PAQ = MoMo physical activity questionnaire, IPAQ = International Physical Activity Questionnaire, GPAQ = Global Physical Activity Questionnaire, YAP = The Youth Activity Profile, ASAQ = The Adolescent Sedentary Activity Questionnaire, * = validated questionnaire.

2020; Yang, et al., 2020). MVPA was reported to decrease between 15 min/day (López-Bueno, et al., 2020) and as much as 91 min/day (Medrano, et al., 2020). MVPA evaluated with the PAQ-A questionnaire decreased on average by 0.7 (Gilic, et al., 2020), 0.3 (Zenic, et al., 2020) and 0.3 points (Elnaggar, et al., 2020) on a scale of 1-5. Two studies reported that the amount of MVPA decreased in 50 % (Ng, et al., 2020) and in 95 % of children and adolescents (Medrano, et al., 2020). One study (Tornaghi, et al., 2020) reported an unchanged amount of MVPA in the whole sample, but a marked increase in MVPA (+316 MET-min/week) in the group of participants who were very active before the restrictive measures. In participants who were insufficiently active prior to the restrictive measures, time spent in MVPA did not change. Similarly, the last study (Yang, et al., 2020) reported an insignificant change in MVPA among high school students.

Changes in type and domain-specific PA

Nine studies (Carroll, et al., 2020; dos Santos Cardoso de Sá, Pombo, Luz, Rodrigues, & Cardovil, 2020; Dragun, et al., 2020; McCormack, Doyle-Baker, Petersen, & Ghoneim, 2020; Mitra, et al., 2020; Munasinghe, et al., 2020; Nyström, et al., 2020; Schmidt, et al., 2020; Yang, et al., 2020) reported a change in the amount of engagement in different types and domains of PA.

Two studies reported that the amount of walking and cycling (Schmidt, et al., 2020) and participation in active transport and leisure walking (Yang, et al., 2020) did not change. On the other hand, two studies (Mitra, et al., 2020; Munasinghe, et al., 2020) reported a reduction in the amount of walking, number of steps, and cycling. Walking decreased by an average of 20 min/day and for 1000 steps/day (Munasinghe, et al., 2020). Cycling decreased in 53 % of the sample (Mitra, et al., 2020).

Three studies (Mitra, et al., 2020; Schmidt, et al., 2020; Yang, et al., 2020) reported that housework predominantly increased or remained unchanged. Gardening was reported to increase by 7 min/day (Schmidt, et al., 2020). Housework increased by 4 min/day (Schmidt, et al., 2020) and 18 min/day (Yang, et al., 2020) or it remained unchanged in about 50 % of the studied sample (Mitra, et al., 2020; Yang, et al., 2020).

Five studies (Dragun, et al., 2020; McCormack, et al., 2020; Mitra, et al., 2020; Schmidt, et al., 2020; Yang, et al., 2020) examined the changes in various activities: PA indoors/outdoors, sports indoors and outdoors, recreational sports, leisure MVPA, etc. On a representative sample, Schmidt et al. (2020) reported a decrease in the total amount of sport (organized/non-organized sport) by 11 min/day. This was due to a reduction in organized sport participation, which decreased to 0 min/day during the restrictive measures. Schmidt et al. (2020) also reported an increase in habitual physical activity by 35 min/day that led to an overall increase in PA during the lockdown. Also, in the study by Mitra et al. (2020), outdoors sport/PA decreased in 64 % of the sample. In contrast, PA at home increased in 49 % of the sample (McCormack, et al., 2020). Other activities, such as outdoors PA (McCormack, et al., 2020), indoors sports/PA (Mitra, et al., 2020), physical recreation (e.g., fitness, dance) (Dragun, et al., 2020) and leisure MVPA (Yang, et al., 2020) remained mostly unchanged. In the last study, leisure MVPA did not change in more than 80 % of the sample.

Two studies reported that the proportion of children playing outside (e.g., playing in the park or in other public open spaces) decreased in more than 50 % of respondents (McCormack, et al., 2020; Mitra, et al., 2020) and that the time spent outside with friends decreased in 71 % of respondents (McCormack, et al., 2020). On the other hand, the amount of indoor play increased in 53 % of respondents. In contrast, Nyström et al. (2020) reported an increase in time spent outside compared to the pre-pandemic period (by 124 min/day during the week and by 68 min/day during the weekend).

The following studies have examined changes in active play outside (Schmidt, et al., 2020), active play and time spent outside (Carroll, et al., 2020), and active play inside and outside (dos Santos Cardoso de Sá, 2020). Activities decreased in two studies for 51% of the sample (Carroll, et al., 2020) and for 83% of the sample studied (dos Santos Cardoso de Sá, et al., 2020). The activity was greatly reduced in 37% of the sample. One study reported that participation in playing outside increased by 21 min/day (Schmidt, et al., 2020).

Changes in meeting recommendations for PA

Eight studies evaluated the change in the proportion of participants who met the MVPA recommendation (at least 60 min/day). Decreases in the proportion of meeting the recommendation have been reported in six studies (Francisco, et al., 2020; Gilic, et al., 2020; Morgül, et al., 2020; Munasinghe, et al., 2020; Ruíz-Roso, et al., 2020; Xiang, et al., 2020), while an increase in the proportion was reported in two studies (Schmidt, et al., 2020; Tornaghi, et al., 2020). Adherence to the PA recommendation decreased by 5% to 42% and increased by 8% to 11%. The largest declines were recorded in Brazil (by -52%; from 59% before the restrictive measures to 7% during the measures), in Spain (by -52%; from 66% before the restrictive measures to 14% during the measures), in China (by -42%, from 50% before the restrictive measures to 18% during the measures), and in Portugal (by -40 %; from 54% before the restrictive measures to 14% during the measures).

Changes in total sedentary time

The total amount of SB was reported in four studies. Three studies reported an increase in SB (Alonso-Martínez, et al., 2021; Dunton, et al., 2020; Yang, et al., 2020), while one study reported a decrease in SB (Dragun, et al., 2020). SB increased by 50 min/day (Alonso-Martínez, et al., 2021), by 0.5 h/day during the weekdays and by 0.7 h/day during the weekends (Yang, et al., 2020), and increased in 63% of children aged 5-8 years and in 83% of children aged 9-13 years (Dunton, et al., 2020). In contrast, Dragun et al. (2020) reported a reduction in sitting time by 2.5 h/day, despite observing an increase in screen time.

Changes in screen time

Changes in total screen time were evaluated in 11 studies (Aguilar-Farias, et al., 2020; Carroll, et

al., 2020; dos Santos Cardoso de Sá, et al., 2020; Francisco, et al., 2020; López-Bueno, et al., 2020; Medrano, et al., 2020; Mitra, et al., 2020; Morgül, et al., 2020; Nyström, et al., 2020; Schmidt, et al., 2020; Xiang, et al., 2020). Significant increases in screen time were reported in all the studies. The total screen time increased between 0.5 h/day (Nyström, et al., 2020) and as much as 28.8 h/week (approx. 4 h/day) (Xiang, et al., 2020). The proportion of children who used screen-based technology for more than 2 h/day during the restrictive measures increased by 54% (Morgül, et al., 2020) and by 40% (Francisco, et al., 2020). Also, studies reported that screen time increased in 70-87% of children (Carroll, et al., 2020; dos Santos Cardoso de Sá, et al., 2020; Medrano, et al., 2020; Mitra, et al., 2020). A very small proportion of children (1-8 %) reduced the use of screen technology.

Change in television viewing time has been evaluated in five studies (Dragun, et al., 2020; McCormack, et al., 2020; Medrano, et al., 2020; Schmidt, et al., 2020; Yang et al., 2020). Three of them indicated an increased television viewing time. Television viewing increased by 21 min/day (Schmidt, et al., 2020), and increased in 59% of respondents (while it remained unchanged in 38%) (McCormack, et al., 2020). In one study, the time spent watching television and using a computer increased by an additional one h/day (Yang, et al., 2020). In two studies, unchanged television viewing time was reported (Dragun, et al., 2020; Medrano, et al., 2020).

Changes in the time spent playing video games were reported in three studies. Two of them indicated an increase in video gameplay (McCormack, et al., 2020; Schmidt, et al., 2020), while one indicated unchanged gameplay (Medrano, et al., 2020). Schmidt et al. (2020) reported an increase in gameplaying by 22 min/day on a representative sample, while McCormack et al. (2020) reported that video gameplaying increased in 56% of participants and remained unchanged in 41% of participants.

Time spent using phones, tablets, and computers has been reported in four studies (Dragun, et al., 2020; McCormack, et al., 2020; Medrano, et al., 2020; Munasinghe, et al., 2020). An increase in mobile phone use was reported in two studies and unchanged phone use was reported in one study. A study where a mobile application was used to record the time when the phone screen is turned on reported an increased phone use by one h/day (Munasinghe, et al., 2020). A study that relied on self-reported data found an increase of 0.5 h/day, and an increased mobile phone usage in 68% of the sample studied (Dragun, et al., 2020). Dragun et al. (2020) also reported an increase in computer and tablet use by 2.5 h/day, and that 78% of participants increased their time spent using computers and tablets. In another study, no changes were reported for leisure-time computer use (Medrano, et al., 2020). The screen time (excluding the time spent watching television and playing video games) increased in 76% of respondents (McCormack, et al., 2020).

The change in internet use was evaluated in three studies (Mitra, et al., 2020; Munasinghe, et al., 2020; Schmidt, et al., 2020). Two studies were conducted on large national representative samples (Mitra, et al., 2020; Schmidt, et al., 2020). An increase in internet and social media use was reported by two studies, while one study indicated mostly unchanged or increased use. Leisure-time internet usage increased by 61 min/day (Schmidt, et al., 2020). Time on social media did not change in 50% of respondents and increased in 45% of respondents (Mitra, et al., 2020).

Discussion and conclusions

The purpose of the literature review was to gather findings from published studies examining the impact of the COVID-19 restrictive measures on PA and SB in children and adolescents. Consistent with our hypothesis, most studies reported that the impact of the COVID-19 restrictive measures on PA and SB in children and adolescents was mostly unfavorable. Engagement in PA was mostly reduced, while SB was mostly increased.

Among the studies that examined changes in PA levels, the results were the most consistent for the reduction of total MVPA. Ten out of 12 studies reported a reduction in time spent in MVPA and only two studies (Tornaghi, et al., 2020; Yang, et a., 2020) reported unchanged behavior. MVPA decreased between 15 min/day (López-Bueno, et al., 2020) and 91 min/day (Medrano, et al., 2020). Regarding total PA levels, three studies reported a decreased activity and one study reported increased activity (Nyström, et al., 2020). It is worth noting that in the latest study the restrictive measures differed from the measures reported in other studies; namely, the restrictive measures did not include the closure of kindergartens, playgrounds, and parks. In addition, kindergartens changed their daily routines in a way that children spent more time outside during the pandemic.

The findings on changes in specific types of PA were more often mixed – studies reported either a decreased level, unchanged or even increased levels of PA. Nevertheless, it can be observed that the activities carried out indoors or at home (e.g., PA/indoor sports, housework) have mostly increased or remained unchanged, while the activities carried out outside (e.g., PA/sports outdoors, walking, cycling) mostly decreased. Housework and gardening did not decrease in any of the studies, but mostly increased or remained unchanged. In contrast, walking and cycling mostly decreased or remained unchanged. Such findings were expected, since the usage of the

public open spaces was commonly restricted and staying at home was encouraged.

Studies examining changes in SB consistently reported an increase in SB among children and adolescents. In addition, the proportion of those who increased their sedentary time was relatively high. The only exception was one study (Dragun, et al., 2020) in which a reduced amount of sitting time was reported, despite the increased screen time. According to the authors, this could be due to the fact that children were not required to sit in school classrooms during the lockdowns, compared to the pre-pandemic period. In addition, children used screen devices as a tool of school teaching, including applications/video games that advertise and encourage participation in PA.

Studies have also been consistent in reporting increased screen time. The total screen time increased in all the reviewed studies between 0.5 h/day (Nyström, et al., 2020) and as much as 28.8 h/week (approx. 4 h/day) (Xiang, et al., 2020). Also, none of the studies reported a reduced usage of specific screen devices (e.g., watching television, using a computer or tablet).

The impact of the COVID-19 restrictive measures on PA and SB was predictable, as the restrictive measures largely limited the movement outside and shifted classroom lessons to attending lessons online. It is known from previous studies that children who spend more time outside are more physically active and less sedentary (Tremblay, et al., 2015). Nevertheless, the reduction of PA during the lockdown was not the only option. For example, some studies reported unchanged levels (Tornaghi, et al. 2020; Yang, et al., 2020) or even increased levels of PA (Nyström, et al., 2020; Schmidt, et al., 2020). Schmidt et al. (2020) discussed that the increase in PA could have resulted from children and adolescents having more leisure time for recreational PA during the lockdown and there might be a greater focus on maintaining health. In another study (Nyström, et al., 2020), the increase in PA was probably the result of a COVID-19 measure suggesting that children should spend more time outside while in kindergarten to lower the risk of virus transmission.

In addition, several studies have reported that the COVID-19 restrictive measures affected older children to a greater extent than the younger ones (Aguilar-Farias, et al., 2020; Dunton, et al., 2020; López-Bueno, et al., 2020; Mitra, et al., 2020; Schmidt, et al., 2020). Average PA level decreased more and more often in older children than in the younger. This could be explained by the fact that the older children need more space for active play (Aguilar-Farias, et al., 2020). Moreover, the increase in SB was also more frequent in older children and adolescents, which could be explained by their greater access to screen technology (Aguilar-Farias, et al., 2020).

Limitations and further directions

For the interpretation of the results, it is necessary to consider the methodology of our systematic review and the limitations of the included studies. We searched only three databases of scientific literature and our search string did not include terms related to specific types of PA and SB. Due to the heterogeneity of outcome measures in the included studies, the meta-analysis was not possible and due to the heterogeneity of measurement tools used, it was difficult to directly compare the studies in some cases. We used NOS for cross-sectional studies that suffered from a lack of evidence on validity and a lack of comprehensive manuals for users (Luchini, Stubbs, Solmi, & Veronese, 2017). However, NOS is frequently used tool for the quality assessment for cross-sectional studies, and inter-rater reliability was found to be satisfactory (Moskalewicz & Oremus, 2020).

The studies included were mostly performed on non-representative samples and about half of the studies were conducted on small samples (less than 1,000 subjects). Convenience sampling, which was present in most of the studies, could lead to results that cannot be generalized to the entire population. At the same time, PA and SB were mostly assessed using subjective methods (e.g., online questionnaires) that were commonly of unknown validity. Only two studies used an objective method – accelerometer (Alonso-Martínez, et al., 2021), pedometer and mobile application (Munasinghe, et al., 2020) – to assess PA and SB. In addition, data collection has often been retrospective, where results may be affected by the respondents' ability to accurately recall information from the more distant past. The recall of information may present additional limitations in young children due to their mental abilities (Dunton, et al., 2020). In studies where children's PA/SB was reported by their parents, parental stress due to the resulting pandemic situation may have affected their perception of changes in children's behavior (Francisco, et al., 2020). Additionally, the data were mostly collected through online questionnaires, so the respondents did not receive additional clarifications from the authors (compared to the personal interview) and could have interpreted the questions differently.

Future studies should aim to use validated tools for the assessment of PA and SB, especially the objective methods that are more reliable and valid (Dunton, et al., 2020). Longitudinal types of research on representative samples (Francisco, et al., 2020) are needed to better understand the impact of the COVID-19 pandemic or similar crisis on PA and SB in children and youth. Future studies could

also examine how long after the end of the restrictive measures the levels of PA and SB will return to their pre-pandemic levels and whether this will happen on its own. Finally, this review showed that there is a need for the development of interventions for maintaining/increasing PA among children and adolescents that would be suitable for implementation during future pandemics and other similar crisis situations.

Our review showed that the COVID-19 restrictive measures have further increased the issue of insufficient PA and excessive SB among children and adolescents. There is a need for interventions that would maintain PA levels and use of screen technology during lockdowns or similar crises. We believe it is also worth raising the awareness of parents, who can greatly influence their children's PA and SB, also by acting as role models. Finally, habits from the early years of life are often passed into adulthood, therefore, children and adolescents exposed to restrictive measures need additional attention.

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