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Bachelor's thesis in Human Movement Science  
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## **Abstract**

**Background:** COVID-19 and the following restrictions forced us to stay at home and changed our daily behaviors completely. This could have had a great impact on children and adolescent's health, moreover their opportunities to perform physical activity. The aim of this literature study was to investigate COVID-19's impact on children and adolescents' physical activity during lockdown and its correlation with changes in sleep, sedentary behavior, and screen time. **Methods:** The literature search was performed in the databases PubMed and Web of Science. The search criteria required that the studies had an observational study design, were conducted in the past three years, and focused on healthy individuals with at least two measurements of physical activity, and at least one of the behaviors screen time, sedentary behavior, and sleep had to be measured. **Results:** Ten articles were included in this literature study, whereas eight of the studies found that PA decreased during the pandemic. In addition, an overall increase in screen time and sedentary behavior, and a decrease in sleep was found during lockdown. **Conclusion:** The COVID-19 pandemic has had an overall negative impact on children's and adolescents' physical activity together with screen time, sedentary behavior, and sleep.

## **Abstrakt**

**Bakgrunn:** COVID-19-pandemien påla samfunnet en rekke begrensninger som førte til at vi måtte endre de daglige vanene våre. Dette kan ha hatt konsekvenser for barn og unges helse, og spesielt deres mulighet til å være fysisk aktive. Formålet med denne litteraturstudien var å undersøke COVID-19s innvirkning på barn og unges fysiske aktivitet, og relaterte endringer i søvn, stillesittende atferd og skjermtid under nedstengningen. **Metoder:** Litteratursøket ble utført i databasene PubMed og Web of Science. Søkriteriene var observasjonsstudier med friske deltakere, publisert innen de tre siste årene, med minst to målinger av fysisk aktivitet, i tillegg til minst to av variablene skjermtid, stillesittende atferd og søvn. **Resultater:** Ti artikler ble inkludert i denne litteraturstudien, hvor åtte fant at nivåene av fysisk aktivitet ble redusert under pandemien. I tillegg viste studiene en økning i skjermtid og stillesittende atferd, samt en nedgang i søvn under nedstengningen. **Konklusjon:** COVID-19-pandemien har hatt en generell negativ innvirkning på barns og unges fysiske aktivitet sammen med skjermtid, stillesittende atferd og søvn.

**Keywords:** COVID-19, lockdown, physical activity, children, adolescents, screen time, sedentary behavior, sleep.

## **Introduction**

The worldwide spread of COVID-19 and the resulting lockdowns have posed a threat to humans' physical activity (PA). This threat has also disrupted other daily behaviors that are closely associated to PA, such as sedentary behavior, screen time, and sleep. The World Health Organization (WHO) declared COVID-19 a global pandemic in March 2020 (1). Since then, it has been a global priority to limit the spread of the virus. This caused several countries to implement a lockdown and apply restrictions such as social distancing, prohibition of leisure activity and remote learning. This has disrupted humans' daily behaviors and limited their opportunities for PA, leading to concerns about potential long-term consequences for their health and well-being.

PA is defined by WHO as any bodily movement produced by skeletal muscles that requires energy expenditure (2). Furthermore, it is recommended that children and adolescents engage in at least an average of 60 minutes per day of moderate-to-vigorous intensity, mostly aerobic, PA, across the week (3). Prior to the onset of COVID-19, WHO conducted a study which revealed that the majority of adolescents across the globe were not in compliance with these guidelines (4). This is concerning due to the many health benefits associated with PA, such as enhancing cardiovascular fitness and strengthening bones and muscles (2). In addition, PA contributes to preventing a range of chronic diseases later in life (2). Furthermore, WHO recommends limiting the amount of time spent being sedentary (5). Decreasing the amount of time spent sedentarily can have a significant positive impact on overall health, as it allows for more time engaged in PA (2).

Sedentary behavior and PA have a direct inverse relation, as one can only increase time in one of them by decreasing time in the other. A 24-hour day consists of sleep and wake time, and during our waking hours we are fluctuating between the state of PA and sedentary behavior. Furthermore, PA can be measured by activity type or intensity, and objectively measured PA and sedentary behavior is typically measured using body-worn accelerometers. Examples of different activity types include running, cycling, standing, and walking. If measured by intensity, PA is typically described in categories of sedentary, light-intensity PA (LIPA), and moderate-to-vigorous PA (MVPA). Thus, a person can increase both their sedentary time and high-intensity activity time, however, this necessarily means they will have less time for either sleep or LIPA as there are still only 24 hours in a day. Furthermore,

sedentary behavior includes sitting and lying down, and there are some behaviors that most of us engage in which are characterized by this, such as sleeping and watching TV. Excessive screen time can have a negative impact on children and adolescents' health (6). In addition to contributing to an increase in sedentary behavior, excessive screen time can lead to a decreased amount of sleep. Furthermore, the blue light that emits from screens can negatively impact sleep (7). This is concerning as sleep is important for children's and adolescents' growth and development, as well as PA (8). PA, sedentary behavior, screen time and sleep are closely intertwined, and a good balance is important to promote overall health and well-being.

It is postulated that the COVID-19 pandemic has led to a reduction in PA and a detrimental impact on other related behaviors, such as screen time, sedentary behavior, and sleep. Given the clear health advantages of PA, it is concerning that the pandemic may be driving a shift in activity patterns among children and adolescents. Consequently, the aim of this literature study is to investigate how the COVID-19 pandemic has impacted children's and adolescents' PA during lockdown. Additionally, we aim to examine how PA is related to changes in sleep, sedentary behavior, and screen time during lockdown.

## **Methods**

The literature search was carried out on the 28<sup>th</sup> of February 2023 using the databases PubMed and Web of Science. Using the keywords "physical activity" OR "inactivity" OR "sedentary behavior" OR "accelerometer" AND "adolescents" OR "children" AND "lockdown" OR "school closure" OR "home education". This gave an initial result of 257 articles in PubMed and 343 articles in Web of Science. The inclusion criteria were 1) observational study, clinical trial or randomized controlled trial, 2) conducted during the past three years, 3) "physical activity" present in the abstract or title, 4) conducted on healthy individuals, 5) at least two times of measurement and 6) in addition to PA, at least one of the behaviors screen time, sedentary behavior and sleep had to be examined. After applying these inclusion criteria there was one article of interest in PubMed and nine articles of interest in Web of Science.

## **Results**

Ten studies investigated how the COVID-19-pandemic affected PA during lockdown. In addition, the studies conducted measurements of at least one of the behaviors screen time,

sedentary behavior, and sleep. The studies revealed that there was an overall decline in PA during the lockdown period. Additionally, those studies that examined screen time and sedentary behavior found a general increase in these behaviors. Conversely, studies that focused on sleep showed an overall decrease in this behavior. The different behaviors examined in the studies are presented in Table 1 to provide insight into the changes in each behavior. The behaviors that are considered not in the scope for this review have not been included in the table.

**Table 1:** Characteristics from studies included from the literature search.

Author, year	Study design	Participants (n, age)	Method	Results
<i>Morrison et al., (2021) (9)</i>	Two-face, repeated-measures study	62, 7-15 y	Questionnaires	PA ↓ Sleep ↓ Screen time ↓
<i>Velde et al., (2021) (10)</i>	Longitudinal cohort study	233, 4-18 y	Accelerometer Questionnaires	PA ↓ Sedentary behavior ↑ Screen time ↑
<i>Tapia-Serrano et al., (2022) (11)</i>	Cross-sectional study	1345, 11-16 y	Questionnaires	PA ↓ Sleep ↓ Screen time ↑
<i>Garcia-Alonso et al., (2022) (12)</i>	Longitudinal study	110, 4-7 y	Accelerometer	PA ↑ Sleep ↓ Sedentary behavior ↑
<i>Benmerzoug et al., (2022) (13)</i>	Cross-sectional study	275, 5-12 y	Questionnaires	PA ↓ Screen time ↑ Sedentary behavior ↑



<i>Jáuregui et al., (2021) (14)</i>	Cross-sectional study	631, 1-5 y	Questionnaires	PA ↓ Screen time ↑ Sleep ↓
<i>Shneor et al., (2021) (15)</i>	Longitudinal study	19, 8-12 y	Accelerometer	PA ↓ Sleep -
<i>Łuszczki et al., (2021) (16)</i>	Cross-sectional study	1016, 6-15 y	Questionnaires	PA ↓ Sleep ↓ Screen time ↑
<i>Hourani et al., (2022) (17)</i>	Cross-sectional study	477, 6-17 y	Questionnaires	PA ↓ Screen time ↑
<i>Gardner et al., (2022) (18)</i>	Prospective cohort study	983, 11-13 y	Questionnaires	PA - Sleep ↑ Screen time ↑

↓ = decrease; ↑ = increase; - = no change; PA = physical activity

**Morrison et al., (2021)** aimed to determine the effects of pandemic movement restrictions on children's PA, screen time and sleep (9). They conducted a two-phase, repeated-measures study to see if they could find any changes in the behaviors from 2018 to 2020. 62 children (aged 7-15 years old) completed a self-assessment questionnaire, first in 2018 and then again in 2020. The study research found that during lockdown MVPA decreased significantly by 46 minutes per day (min/day). In terms of screen time, the average min/day was  $118.1 \pm 56.0$  prior to lockdown and decreased with 13.7 % to  $72.7 \pm 35.0$  min/day during lockdown. Sleep duration was also consistently lower during lockdown compared to when there were no restrictions (95% CI: -104.1 to -45.5 minutes,  $p < 0.001$ ).

**Velde et al., (2021)** conducted a longitudinal cohort study that aimed to investigate the effects of the COVID-19 pandemic on PA behavior and screen time on children in the Netherlands (10). The study used both objective and subjective measures of PA, and subjective measures of screen time before, during and after-school closures. The data was

collected from two different cohorts. In cohort A 102 children (aged 4-18 years old) completed a self-administered questionnaire in May 2020 and then a follow-up questionnaire 3 weeks later. Cohort B consisted of 131 children (aged 7-12 years old) who were provided with accelerometers in May-June 2019. They also completed a questionnaire during this period. In June 2020 a subgroup of children from cohort B filled out a follow-up questionnaire, and accelerometer data were collected. In cohort A, 62% reported a decrease in total PA. Meanwhile, self-reported screen time in both cohort A and B increased with an average of 43,8 min/day during lockdown. In cohort B, sedentary behavior measured by accelerometry increased by an average of  $45 \pm 10$  min/day and only 20% reached the recommended 60 minutes of PA per day, compared to 64% in May 2019.

**Tapia-Serrano et al., (2022)** conducted a repeated cross-sectional study in two different samples of Spanish children and adolescents at different times; one before the pandemic and one during the pandemic (11). The aim of the study was to investigate changes in adherence to the Canadian 24-Hour Movement Guidelines. The guidelines recommends that children and adolescents aged 5-17 years old should accumulate 60 minutes of MVPA per day and spend less than two hours of recreational screen time per day. In addition, a sleep duration between nine and eleven hours per day (aged 5-13) and eight to ten hours per day (aged 14-17) (19). Firstly, a sample of 844 students completed a questionnaire regarding their PA, recreational screen time and sleep duration in 2018. Secondly, a different sample of 501 students completed the same questionnaire. The study found that the percentage of adolescents meeting the PA recommendations decreased from 35.2% before the pandemic to 23.4% during the pandemic ( $p < 0.001$ ). Sleep duration decreased from 8.66 hours/day before the pandemic to 7.10 hours/day during the pandemic ( $p < 0.001$ ). Recreational screen time increased from 4.52 hours/day before the pandemic to 5.45 hours/day during the pandemic ( $p < 0.001$ ).

**Garcia-Alonso et al., (2022)** compared PA, sedentary behavior, and sleep time in children prior to and during the COVID-19 pandemic using a longitudinal study design (12). A total of 110 children (aged 4-7 years old) wore GENEActiv accelerometers for six days prior to the pandemic, and again one year into the pandemic. Garcia-Alonso et al. found an increase in MVPA during the pandemic, with a mean difference of 10.70 min/day (95% CI: 4.18 to 17.22). Sedentary behavior increased during the pandemic with a mean difference of 31.59

min/day (95% CI: 13.08 to 50.10). Furthermore, a decrease in sleep time during the pandemic was found, with a mean difference of -0.60 hours/day (95% CI: -0.80 to -0.39).

**Benmerzoug et al., (2022)** conducted a cross-sectional study in children (aged 5-12 years old) using the same online survey before and during the pandemic to assess the effects of the COVID-19 induced restrictions (13). The questionnaire consisted of more than 40 questions regarding PA, sleep and sedentary behavior. 275 questionnaires out of 461 was completed twice. The study showed that sports practice decreased from 52.4% to 30.2%, sedentary behavior increased and screen time (more than two hours/day) increased from 3.3% to 5.5%.

**Jáuregui et al., (2021)** aimed to investigate the correlated changes in movement behaviors from before to during lockdown in a sample of toddlers and preschoolers in Mexico using a cross-sectional study design (14). A total of 631 children (aged 1-5 years old) were included. Data on PA was collected using an online survey which the caregiver answered on behalf of the child. The study found that total PA decreased from 234.3 min/day before the pandemic to 174.0 min/day during the pandemic. MVPA also decreased from 116.2 min/day before the pandemic to 81.7 min/day during the pandemic. Additionally, screen time increased from 97.5 min/day before the pandemic to 192.8 min/day during the pandemic. Finally, sleep time decreased from 13.8 hours/day before the pandemic to 13.6 hours/day during the pandemic.

**Shneor et al., (2021)** conducted a longitudinal study to evaluate the effects of pandemic-related restrictions on the behavior of children, using objective measures (15). A total of 19 boys (aged 8-12 years old) were assessed before and during the pandemic. The behaviors measured were PA, MVPA and sleep. Comparing the behaviors before and during the restrictions, the study found that mean daily PA decreased from  $595 \pm 145$  counts per minute (CPM) to  $429 \pm 139$  CPM ( $p = 0.001$ ), while MVPA decreased from  $86 \pm 39$  minutes to  $46 \pm 30$  minutes ( $p = 0.004$ ). The sleep duration remained similar before and during the pandemic.

**Luszczki et al., (2021)** conducted a cross-sectional study comparing PA, screen time, and hours of sleep among Polish children and adolescents (aged 6-15 years old) before and during the COVID-19 pandemic (16). The study obtained self-reported data from 1016 participants once in February/March 2020 and then again, a year later in 2021. It was found that the participants were more physically active in 2020 than in 2021. Before the pandemic, the average PA level was 4 days with 60 minutes or longer, which decreased to 3 days during the

pandemic. In addition, the percentage of children meeting the recommended level of PA dropped from 12.3 % before the pandemic to 9.2 % during the pandemic. The obtained data also showed a significant decrease in duration of sleep. On weekdays, the sleep time was reduced from 8.83 to 8.55 hours, and on weekend, it decreased from 10.11 to 9.55 hours. Significant differences were also found in the time spent watching TV and/or browsing the internet, with children watching more during the pandemic on weekdays but not on the weekend. The percentages of children watching over 6 hours per day increased from 1.3 % to 5.1 % ( $p = 0.0016$ ).

**Hourani et al., (2022)** conducted a cross-sectional study in a sample of 477 Jordanian children and adolescents (aged 6-17 years old) (17). The study assessed the effect of the COVID-19 lockdown on PA and screen time. The study group completed a questionnaire before and during lockdown. The participants were split in to two groups; children aged 6-12 years old and adolescents aged 13-17 years old. Both age groups reported an increase in screen time during lockdown. Physical inactivity also increased during lockdown, with more than 50% of the subjects reporting little or no PA.

**Gardner et al., (2022)** conducted a prospective cohort study to examine changes in the prevalence of chronic disease risk factors from before and during COVID-19 to evaluate whether differences over time are associated with lockdown (18). The risk factors included behaviors such as physical inactivity, sleep, and screen time. The study consisted of 983 Australian adolescents (aged 11-13 years old). The participants completed self-report assessments prior to the beginning of the pandemic, July-November 2019 and during the pandemic July-October 2021. During the COVID-19 pandemic, the participants had a 26 % decrease in insufficient sleep ( $PR = 0.74$  95% CI = 0.68 to 0.81), and a 6 % increase in excessive recreational screen time ( $PR = 1.06$ , 95 % CI = 1.03 to 1.11). There was no change in the prevalence of insufficient PA ( $PR = 1.03$ , 95% CI = 1.00 to 1.07).

## **Discussion**

The COVID-19 pandemic has brought about unprecedented changes in the way we live. The ten articles included in this study investigated the impact of the pandemic on PA, screen time, sedentary behavior, and sleep among children and adolescents. The studies aimed to examine the changes in PA during the pandemic and assess the influence of social distancing measures, leisure activity restrictions, and remote learning on the daily routines of children

and adolescents. Overall, the findings suggest that the COVID-19 pandemic and associated lockdowns have had a negative impact on children's and adolescents' daily routines, including their PA. Among the included studies, one revealed an increase in PA during the pandemic (12), another reported no significant change in PA (18), while the remaining eight studies found a decline in PA (9–11,13–17). This decline is concerning as it is well documented that regular PA offers significant health benefits (20). However, factors such as characteristics of the study group and methods measuring PA could influence the findings, and these will be discussed in further detail.

### *Characteristics of the study group*

This literature study had a wide range of sample sizes, ranging from 11 to 1345 participants, indicating a significant difference. Seven of the initial studies had sample sizes exceeding 233, while the remaining three studies had 110 or fewer participants. The study conducted by Shneor et al. included the fewest participants with only 19 children, and although the decrease in PA was statistically significant, it can be challenging to determine whether this finding is representative for the general population (15). The diversity in sample sizes may affect the validity of the results, with larger samples providing a more accurate representation of the population (21). Therefore, the findings from studies with smaller samples should be interpreted with caution. Additionally, there was a large age range between the study samples, varying from 1 to 18 years old. PA, sedentary behavior, screen time and sleep can differ significantly between a one-year-old and an 18-year-old due to differences in their developmental stages and physical abilities. These differences can also affect the motivations and interests of children and adolescents in physical activities.

Additionally, there could be factors influencing the opportunity for PA during the pandemic, such as differences in government responses to COVID-19. There was a large geographical spread in the included studies, which complicates making meaningful comparisons as some governments imposed stricter restrictions than others. Shneor et al.'s and Gardner et al.'s studies were conducted on individuals in Israel and Australia which were under strict stay-at-home orders, permitted to leave the home only for essential reasons (15,18). In contrast, ten Velde et al. measured PA among children living in the Netherlands, a country that allowed greater freedom of movement during the pandemic (10). This difference in availability of PA could strongly influence the findings.

### *PA and sedentary behavior during lockdown*

The majority of adolescents worldwide did not adhere to the PA recommendations prior to the pandemic, making it concerning that the studies in this review show an overall decrease in PA. This finding is consistent with that of Hyunshik et al. who in a longitudinal study showed that PA and adherence to the WHO-recommended guidelines decreased significantly among Japanese preschoolers during COVID-19 (22). In this review, seven of the studies found that when PA decreased during the pandemic, there was a corresponding decrease in sleep and an increase in sedentary behavior and screen time (10,11,13–17). This amplifies that these behaviors are closely linked, although the cross-sectional nature of the studies does not allow inferring direction of the relationship between these behaviors (19). These findings largely suggest that the pandemic restrictions have led to a negative trend in these behaviors.

However, three particular studies (9,12,18) deviated from this trend, yielding results that encourage further discussion. Morrison et al. reported a reduction in screen time (9), Garcia-Alonso et al. documented an increase in PA (12), while Gardner et al. found an increase in sleep duration with no accompanying changes in PA (18).

The study by Morrison et al. showed a decrease in screen time during lockdown in a sample of 62 7-15 years old children in Slovenia. A possible explanation to this decrease is that the questionnaire was designed to measure recreational screen time. Thus, overall screen time likely increased due to the amount of time spent in front of screens as a result of remote learning. However, the studies conducted by Tapia-Serrano et al. and Gardner et al. measured recreational screen time as well, and found that screen time increased during the pandemic (11,18). Increased recreational screen time and its sedentary characteristic poses a concern, as it limits the time available for PA.

The study by Gardner et al. found that PA levels remained the same during the pandemic and that sleep duration improved, in a sample of 983 adolescents aged 11-13 years old in Australia (18). This contrasts the trends described in the other studies, especially as this study found an increase in the prevalence of excessive recreational screen time, which is often considered a primary contributor to poor sleep (23). During lockdown, some propose that the time usually spent on preparing and commuting to school was used to obtain more sleep (18). However, this increase was not found in any of the other included studies, which experienced school closures and remote learning as well. Furthermore, Gardner et al. showed that the prevalence of insufficient PA remained stable during lockdown. A possible explanation to

this is that the data was collected during the 2021 lockdown, and that adolescents had already adapted to the pandemic and found other ways to achieve their PA. This can be supported by Garcia-Alonso et al's findings that PA increased, which was also assessed one year into the pandemic (12). On the contrary, Tapia-Serrano et al., Luszczki et al., and ten Velde et al. found a decrease in PA despite the pandemic having lasted for a while when they conducted their studies (10,11,16).

Interestingly, the study by Garcia-Alonso et al. showed an increase in PA in a sample of 110 4-7 years old children in Spain (12). This contrasts typical trends and previous research on PA levels during the pandemic (18). It is noteworthy that this relatively small sample size might not be fully representative for the general Spanish population. Moreover, the increase in PA occurred during the COVID-19 pandemic, a time when many people were staying at home to prevent the spread of the virus. However, there was also a great awareness around health at this time, which may have encouraged people to stay active. In this study the parents were informed about the study objectives in advance, which could have influenced the children's PA levels due to parental encouragement. However, this remains speculative and further investigation would be needed to confirm this. Another potential explanation for the increase in PA could be related to the social restrictions, which may have resulted in children spending more time with their families. As young children often rely on caretakers for supervision and companionship, increased family time may have translated into higher PA levels. Lastly, the study findings by Garcia-Alonso et al. showed an increase in sedentary behavior. This can be elucidated by the fact that PA measured by accelerometers is categorized based on its intensity; sedentary, LIPA, and MVPA. In cases where children increased their MVPA while also increasing their sedentary time, it may be inferred that they compensated for the additional time spent on MVPA by reducing their engagement in LIPA or sleep, as supported by the observed decrease in sleep in this study. As pointed out by the researchers of this study, some children's transition from early childhood education to primary education could explain the increase in sedentary behavior, as it involves a shift towards more sedentary activities like sitting at desks.

There could be several factors related to the restrictions that contribute to changes in PA, screen time, sleep and sedentary behavior. Numerous children and adolescents were deprived of school-based PA opportunities due to the implementation of remote learning. This reduced the amount of time they spent commuting to school. It also made them miss out on

opportunities for daily PA such as recess and physical education, which could be important sources of PA for many of them. In terms of screen time, remote learning has led to an increase in screen time for many children and adolescents, as they spent more time in front of screens for school-related activities than before the pandemic. The remote learning and the following increase in screen time is a concern, as excessive screen time has been linked to negatively impact sleep and increase sedentary behavior (24). The impact of remote learning on PA, screen time, and sedentary behavior among children and adolescents is complex and may vary depending on individual circumstances such as access to resources, motivation, and support. It is important for parents and educators to encourage and support healthy habits, including regular PA, limited screen time, and reduced sedentary behavior, during remote learning and beyond.

As a result of the COVID-19 pandemic and associated restrictions, sports facilities and community centers were closed in many countries. The closure of these facilities reduced children's and adolescents' opportunities for organized and supervised physical activities. Consequently, they may experience a reduction in PA, as time previously allocated to sports facilities may be replaced by sedentary behaviors, such as playing video games or watching TV. This could lead to an increase in screen time and sedentary behavior, which could have negative implications for their health and well-being. In addition, the need to maintain social distancing may have made it challenging for children and adolescents to participate in team sports or other group PA, which under normal circumstances could account for a large portion of their daily PA.

#### *Validity and reliability of the methods measuring PA and sedentary behavior*

Various weaknesses in the study designs and the implementation of the studies may present a somewhat limited opportunity for the interpretation of the results. The studies in this literature search employed different methods to assess PA, sedentary behavior, screen time and sleep. The diverse methods of measuring could have an impact on the outcomes of the studies, and certain measures may exhibit greater reliability and validity compared to others. For example, the objective measures using accelerometers generally provides more accurate estimates than a questionnaire when measuring PA (14). Due to the restrictions making it difficult to use objective measures, seven of the studies used questionnaires (9,11,13,15–18), whereas the remaining studies used objective methods (10,12,14). Collecting data through subjective methods can be prone to various sources of errors, as they are susceptible to biases



(25). When answering an online survey about daily behaviors, recall bias, social desirability bias and misunderstandings can easily occur, which can affect the validity and reliability of the study (25).

Additionally, it can be a lot to expect the youngest children to have an understanding of what PA implies. Thus, in some of the studies, parents answered the questionnaires on behalf of their children (10,13,14,17). This could affect the reliability and validity of the answers, as parents could have biased responses or lack of knowledge regarding their child's PA. Lastly, due to variations in the questions in the studies' questionnaires, it can be difficult to make meaningful comparisons. Due to the factors mentioned above, it is important to read the results from the studies with caution, as they may contain factors that weaken statistical significance and the basis of comparison.

#### *Future studies*

Overall, the studies indicated a negative trend in PA, sedentary behavior, screen time and sleep, and this raises concerns about the potential consequences if these habits persist in a post-COVID-19 life. Thus, studying the long-term effects is crucial to better understand their potential impact on public health. By studying the long-term effects, researchers can identify potential risks and develop strategies to mitigate any negative consequences of prolonged lockdown measures. Moreover, such studies could provide insights into the efficacy of lifestyle interventions, which could help promote healthier behaviors in the future. Therefore, investigating the long-term effects of the pandemic on these behaviors is essential for developing evidence-based interventions to promote healthy living in the post-COVID-19 era. Further research is needed to determine the underlying factors that influence these behaviors and their relationships with each other.

#### **Conclusion**

According to this review of ten studies, the COVID-19 pandemic has had a negative impact on the investigated behaviors of children and adolescents, including their PA. Eight of the studies found that PA decreased during the pandemic. In addition, the studies revealed a general adverse influence on sedentary behavior, screen time, and sleep. However, additional research is required to investigate if these behaviors are maintained over time, in the absence of social restrictions. Many studies have been conducted comparing PA before and during the pandemic, however, COVID-19 is still highly current and by far the most extensive

coronavirus we have faced so far. Therefore, the long-term consequences have yet to be fully understood. Thus, a better understanding of the pandemic's influence on PA is of great interest to increase our knowledge and to better adapt to a future health crisis.

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