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## Socio-demographic correlates of health behaviors of children and adolescents during the COVID-19 pandemic: a cross-sectional study

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This study aimed to assess the socio-demographic correlates of health behaviors and their changes during the COVID-19 pandemic. A population-based sample of children (3–17 years) was randomly selected between 12/2021 and 06/2022 in Geneva, Switzerland. Parents reported about children’s screen time, physical activity, green spaces time, sleep duration, and whether these changed due to the pandemic. Socio-demographic correlates of changes in health behavior and adherence to corresponding recommendations were evaluated. Of 2104 children, approximately 1/3 did not meet screen or physical activity recommendations, 22% did not sleep sufficiently. Older children and girls were less likely to meet behavior recommendations. During the pandemic, physical activity, green spaces time and sleep quality remained unchanged for most children (72.9%, 72.2% and 93.1%, respectively), while 51.9% experienced an increase in screen time. Older age was associated with a worsening of health behaviors, while children from disadvantaged households were more likely to experience any changes, whether positive or negative. Between 20% and 30% of children fail to meet health behavior recommendations. The COVID-19 pandemic possibly exacerbated existing disparities among older and socio-economically disadvantaged children, although positive changes were also reported. Continuous monitoring and targeted interventions are crucial to promoting healthy lifestyles among youth in the post-pandemic period.

**Keywords** Children, Adolescents, Health behaviors, COVID-19, Physical activity, Screen time, Sleep duration, Green spaces

Health behaviors play a crucial role in the physical and mental health of children and adolescents<sup>1,2</sup>. Prolonged measures taken to curb the spread of the COVID-19 pandemic, such as remote schooling, limitation of in-person contacts and restricted access to recreational facilities, disrupted health behaviors of young people, at least temporarily<sup>3</sup>. This is supported by meta-analyses reporting a 52% increase in screen time<sup>4</sup>, a 20% decrease in physical activity<sup>5</sup>, and an increased sleep duration paired with decreased sleep quality<sup>6</sup> in children and adolescents, two years into the pandemic. The magnitude of these changes appeared smaller in countries with milder restrictions<sup>7</sup>. For instance, in Switzerland, outdoor exercise and walking were never prohibited, unlike in neighboring countries such as Italy and France, where only essential trips were allowed during the initial lockdown<sup>8</sup>. Differences in opportunities for physical and non-screen-based activities persisted in later stages of the pandemic, as access to recreational facilities required proof of vaccination, recovery, or a negative test from 16 years old in Switzerland<sup>9</sup> compared to 12 years old in France and Italy<sup>10,11</sup>.

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Socially disadvantaged young individuals may have been particularly vulnerable to a deterioration in lifestyle. Indeed, unfavorable socio-economic circumstances are associated with lower access to green spaces<sup>12</sup>, which proximity was shown to be key in fostering outdoor recreational activities and limiting screen time during the pandemic<sup>13</sup>. Furthermore, socio-economically disadvantaged families were at heightened risk of financial and parenting strain<sup>14</sup> possibly reducing the parental availability to encourage healthy behaviors in their children.

Only a few population-based studies empirically investigated whether the social patterning of children's and adolescents' health behaviors changed with the pandemic<sup>15–17</sup>. A Chilean study found that among young children, higher parental education was associated with a greater increase in screen time and a greater decrease in physical activity behaviors, while a higher income was protective against a decline in sleep quality<sup>15</sup>. On the contrary, in Hong-Kong, children and adolescents with high family affluence more frequently reported an increase in exercise time than their less advantaged peers<sup>16</sup>. These studies showed inconsistent findings, were conducted early in the pandemic and could not assess lasting changes in behaviors and in their social distribution. Furthermore, government response to the pandemic varied widely and there is little evidence from countries with relatively light restrictions, such as Switzerland<sup>18</sup>.

We thus aimed to (1) estimate children's and adolescents' (referred to as children hereafter) adherence to health behavior recommendations two years into the COVID-19 pandemic, (2) investigate demographic and socio-economic correlates of adherence to those recommendations, and (3) examine correlates of perceived behavior changes because of the pandemic, in Geneva, Switzerland.

## Results

Overall, 2104 children (mean age: 10.2 years; 49.3% girls) were included (Table 1). When weighted by the Geneva population's age and sex distribution, approximately one in three children did not meet screen time or physical activity recommendations (32.0% and 31.8%, respectively), while 21.8% did not sleep sufficiently, with important variations according to age (Table 1). On average, children spent 4 h 51 min per week in green spaces.

The older the children, the less likely to adhere to recommendations, whichever the behavior (Fig. 1). Girls, especially older ones, displayed lower adherence to physical activity and sleep guidelines than boys, and spent less time in green spaces (Supplementary Table 1). Overall, children of parents with a low educational level were less likely to meet recommendations than those of highly educated parents, although this pattern varied depending on child age and behavior type. Educational differences seemed to decrease with age for recreational screen time and sleep duration, while they reversed for physical activity, and remained constantly non-significant for time spent in green spaces (Fig. 1). Results were similar when examining parents' birth country and household financial situation (Supplementary Fig. 1).

Two years into the pandemic, parents estimated that physical activity, green spaces time and sleep quality had remained unchanged for most children (72.9%, 72.2% and 93.1%, respectively). A smaller proportion of children experienced either an increase or decrease in physical activity and green spaces time, or a worsening in sleep quality (Table 2). Changes in recreational screen time were the most prevalent, with an increase reported for about half of children (51.9%). When evaluating correlates of pandemic-related changes, older age was associated with an increased likelihood of a worsening of all four health behaviors (Table 2). Additionally, the odds of decreased physical activity were 1.43 (95% CI: 1.03–2.00) and 1.53 (95% CI: 1.16–2.03) times higher among children of parents with a lower educational level or born outside of Switzerland, respectively. Similarly, the odds of reduced time spent in green spaces were 1.78 (95% CI: 1.23–2.57) and 1.59 (95% CI: 1.17–2.17), respectively, for these groups. Compared with a very good household financial situation, average-to-poor circumstances were associated with an increase in recreational screen time, as well as with both an increase/improvement or decrease/worsening in physical activity, green spaces time and sleep quality (Table 2).

## Discussion

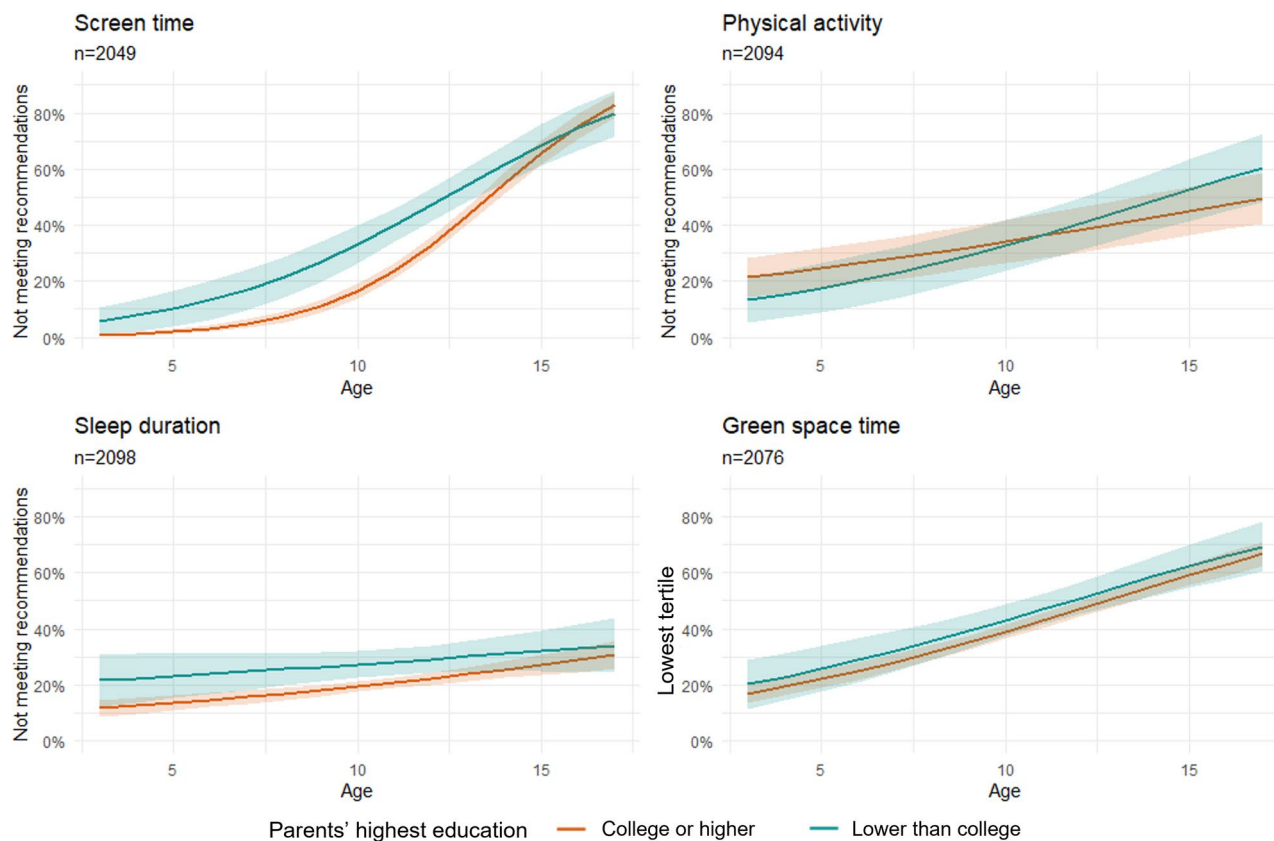
A meaningful proportion of children did not meet health behavior recommendations in 2022, particularly among girls and adolescents. Socio-economic patterns varied depending on age and behavior type. The COVID-19 pandemic triggered both an improvement and worsening of behaviors, although most children in our sample did not experience pandemic-related changes. Older children were at increased risk of an overall worsening of health behaviors due to the pandemic, while children from disadvantaged households were more likely to experience any changes, whether positive or negative.

The prevalence of children meeting screen and sleep recommendations in 2022 was comparable to Swiss estimates of fall 2020, one year into the pandemic<sup>19</sup>. Indeed, schools were open in both periods and children's routine was probably similar. On the other hand, our estimates of adherence to physical activity guidelines were higher than reported in Switzerland in fall 2020<sup>19</sup>, possibly because organized physical activities were still limited in 2020, as opposed to 2022 when the current study took place. This implies that lifting pandemic-related restrictions had a positive effect on children's physical activity. Conversely, non-adherence to recommendations for screen time and sleep duration persisted at the high levels observed during the first year of the pandemic and might require close monitoring.

As commonly observed, correlates of not meeting recommendations included older age for all of the behaviors under study<sup>20–22</sup> and female sex for physical activity<sup>20</sup>. However, adolescent girls' lower adherence to sleep guidelines was surprising in our study<sup>22</sup>. The differences in socio-economic patterns according to age and behavior type reflected previous findings for physical activity and screen time<sup>23</sup>. These variations might explain the inconsistent results of systematic reviews examining socio-economic inequalities in health behaviors among young people<sup>20,21,24,25</sup> and are in line with the equalization hypothesis, which posits that health disparities decrease in adolescence because of the growing influence of peers over the family<sup>26</sup>. These results suggest that

	Total (n = 2104)	Leisure screen time (n = 2054)		Physical activity (n = 2099)		Green spaces time (n = 2081)		Sleep duration (n = 2101)	
		Average hours/day	Not meeting recommendation	Average hours/day	Not meeting recommendation	Average hours/week	Lowest tertile	Average hours/day	Not meeting recommendation
	n (%)	mean (SD)	n (%)	mean (SD)	n (%)	mean (SD)	n (%)	mean (SD)	n (%)
Total	2104 (100.0)	1h36 (1h36)	589 (28.7)	1h24 (0h48)	666 (31.7)	4h48 (4h42)	857 (41.2)	9h30 (1.06)	449 (21.4)
Weighted prevalence		1h43	32.0%	1h22	31.8%	4h51	41.6%	9h30	21.8%
	n (%)	average (95% CI)	% (95% CI)	average (95% CI)	% (95% CI)	average (95% CI)	% (95% CI)	average (95% CI)	% (95% CI)
Age <sup>a</sup>									
Children (3–11 yo)	1288 (61.2)	0h53 (0h49–0h57)	10.0 (8.4–11.7)	1h30 (1h27–1h33)	24.7 (22.4–27.1)	5h46 (5h31–6h01)	30.1 (27.5– 32.6)	9h57 (9h54–10h00)	15.8 (13.8–17.8)
Adolescents (12–17 yo)	816 (38.8)	2h53 (2h47– 2h58)**	59.8 (56.3– 63.3)**	1h09 (1h06– 1h12)**	41.8 (38.4– 45.2)**	3h17 (2h58– 3h36)**	58.6 (55.2– 62.0)**	8h44 (8h40–8h48)**	29.7 (26.5– 32.8)**
Sex <sup>a</sup>									
Male	1066 (50.7)	1h40 (1h35–1h44)	20.5 (17.6–23.4)	1h29 (1h26–1h32)	24.5 (21.8–27.1)	5h12 (4h55–5h28)	36.0 (32.9– 39.0)	9h30 (9h27–9h33)	17.7 (15.4–20.0)
Female	1038 (49.3)	1h36 (1h31–1h40)	19.8 (16.9–22.7)	1h14 (1h12– 1h17)**	37.8 (34.8– 40.8)**	4h24 (4h08– 4h41)**	44.6 (41.4– 47.8)**	9h28 (9h25–9h31)	24.2 (21.5– 26.8)**
Parents’ birth country									
At least one in Switzerland	1265 (60.1)	1h36 (1h32–1h40)	18.4 (15.8–21.0)	1h21 (1h19–1h24)	30.6 (28.0–33.2)	4h56 (4h41–5h10)	41.1 (38.2– 44.0)	9h33 (9h30–9h36)	18.4 (16.2–20.5)
Outside of Switzerland	833 (39.6)	1h41 (1h36–1h46)	22.4 (19.1–25.8)*	1h22 (1h19–1h25)	31.0 (27.8–34.2)	4h35 (4h17–4h54)	38.8 (35.3– 42.3)	9h22 (9h19–9h25)**	24.4 (21.4– 27.4)**
Missing	6 (0.3)								
Parents’ highest education									
College or higher	1737 (82.6)	1h33 (1h29–1h36)	17.9 (15.7–20.2)	1h21 (1h19–1h24)	30.6 (28.3–32.8)	4h54 (4h41–5h06)	39.4 (36.9– 41.8)	9h31 (9h28–9h33)	19.6 (17.7–21.4)
Lower than college	362 (17.2)	2h04 (1h56– 2h12)**	30.0 (24.4– 35.6)**	1h23 (1h18–1h28)	31.6 (26.7–36.5)	4h21 (3h53– 4h48)*	44.1 (38.7– 49.5)	9h20 (9h15–9h25)**	26.5 (21.9– 31.1)**
Missing	5 (0.2)								
Household financial situation									
Very good	724 (34.4)	1h30 (1h25–1h35)	17.8 (14.6–21.1)	1h23 (1h20–1h27)	27.9 (24.5–31.2)	5h09 (4h49–5h29)	36.8 (33.0– 40.5)	9h36 (9h33–9h40)	19.6 (16.7–22.6)
Good	856 (40.7)	1h38 (1h33– 1h43)*	20.9 (17.7–24.2)	1h20 (1h17–1h23)	32.8 (29.6–36.1)*	4h36 (4h18– 4h55)*	41.9 (38.4– 45.4)	9h28 (9h25–9h31)**	18.7 (16.1–21.4)
Average to poor	366 (17.4)	1h52 (1h44– 1h59)**	24.0 (19.0–29.1)*	1h24 (1h19–1h28)	30.7 (25.9–35.6)	4h49 (4h21–5h17)	40.7 (35.3– 46.0)	9h19 (9h14–9h24)**	27.4 (22.8– 32.0)**
Missing	158 (7.5)								

**Table 1.** Time spent engaging in health behaviors and non-adherence to corresponding recommendations according to socio-demographic characteristics among children and adolescents, in Geneva, Switzerland, 2022. \* for p-values < 0.05, \*\* < 0.01. SD: standard deviation; CI: confidence interval. Weighted prevalence according to the Geneva population’s age and sex distribution (OCSTAT 2022, reference n° 32). Estimates of health behaviors according to socio-demographic characteristics from marginal prediction after age- and sex-adjusted regressions. Reference groups for age, sex, parents birth country, parents’ highest education and household financial situation comparisons are aged 3–11 years old, male, at least one parent born in Switzerland, college or higher and very good, respectively. <sup>a</sup> Estimates according to age adjusted for sex only, and estimates according to sex adjusted for age only.



**Fig. 1.** Predicted proportion of children not meeting health behavior recommendations according to age and parents' highest education in Geneva, Switzerland, 2022. Results are from generalized estimating equations adjusted for sex (and physical limitations for physical activity), shaded areas correspond to the 95% confidence interval. Analyses performed on complete cases.

public health interventions need to be tailored, targeting children from lower socio-economic backgrounds and adolescents, who are at greater risk for non-adherence to health behavior recommendations.

Most children in our sample did not report lasting changes in health behaviors two years after the onset of the pandemic and following the lifting of all sanitary measures. These reassuring findings could reflect both the resiliency of young people and their families, as well as the relatively light restrictions implemented by the Swiss government<sup>18</sup>. However, when examining socio-demographic patterns of change, we found an overall worsening of health behaviors among older children during the pandemic. Interestingly, compared with their more privileged counterparts, disadvantaged individuals were more likely to experience any changes, whether positive or negative. It reflects results from studies showing that adults whose financial situation deteriorated during the pandemic were more likely to experience both an improvement and worsening of health behaviors such as screen time, substance use, diet and physical activity<sup>27,28</sup>. Disruptive life events, such as the COVID-19 pandemic, can drive lifestyle shifts<sup>29</sup>. Since children with unfavorable financial situation were shown to experience a heightened impact of the pandemic than their more advantaged peers<sup>30</sup> it may explain why they were also more likely to report changes in health behaviors, whichever the direction. These results shed light on the complexity of the social impacts of the pandemic and suggest that additional contextual factors, such as family circumstances, access to green spaces, or housing, might modify the effect of the pandemic<sup>13,27</sup>.

The major strength of this study was the ability to study the correlates of both negative and positive pandemic-related changes in multiple health behaviors in a large population-based sample of children and adolescents. However, results should be interpreted in light of their limitations. As commonly observed in epidemiological surveys<sup>31</sup>, privileged individuals were more likely to participate in our study despite the random selection process (75% of mothers had a university-level education in our sample versus 48% of women aged 25–64 years old, in Geneva<sup>32</sup>), which could lead to an overestimation of the prevalence of children meeting health behavior recommendation. Additionally, the reliance on cross-sectional parent-reported data could be subject to social desirability and recall bias, particularly regarding pandemic-related changes in health behaviors. However, in the absence of objective assessment of health behaviors, parental report may be more reliable than school-aged children's, as it was shown to correlate with objectively measured health outcomes like overweight, whereas child report was not<sup>33</sup>. Finally, no population-based cohort study of children was ongoing in Switzerland at the onset of the pandemic, which proved to be a significant limitation in assessing the pandemic's impact on children's

	Recreational screen time (n = 1938)		Physical activity (n = 1987)		Time in green spaces (n = 1948)		Sleep quality (n = 2104)	
	Increase (n = 1005 ; 51.9%)	Decrease (n = 24 ; 1.2%)	Increase (n = 189 ; 9.5%)	Decrease (n = 350 ; 17.6%)	Increase (n = 264 ; 13.6%)	Decrease (n = 277 ; 14.2%)	Improvement (n = 21 ; 1.0%)	Worsening (n = 125 ; 5.9%)
	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)
Age <sup>a</sup> (years)	1.10 (1.08–1.13)**	1.14 (1.04–1.26)**	1.00 (0.95–1.04)	1.16 (1.12–1.20)**	0.96 (0.93–1.00)*	1.08 (1.04–1.11)**	0.96 (0.85–1.09)	1.07 (1.02–1.13)**
Sex <sup>b</sup>								
Male	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Female	1.05 (0.89–1.24)	1.02 (0.47–2.22)	0.89 (0.67–1.17)	1.02 (0.82–1.28)	0.93 (0.74–1.17)	1.00 (0.78–1.27)	2.13 (0.86–5.31)	1.39 (0.97–1.99)
Parents' birth country								
At least one parent born in Switzerland	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Parents born outside of Switzerland	1.10 (0.89–1.37)	1.44 (0.62–3.31)	0.95 (0.66–1.37)	<b>1.53 (1.16–2.03)**</b>	1.17 (0.86–1.59)	<b>1.59 (1.17–2.17)**</b>	1.10 (0.47–2.57)	0.90 (0.60–1.37)
Parents' highest education								
College or higher	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Lower than college	1.05 (0.80–1.39)	1.00 (0.34–2.96)	1.30 (0.86–1.97)	<b>1.43 (1.03–2.00)*</b>	1.21 (0.83–1.77)	<b>1.78 (1.23–2.57)**</b>	<b>3.11 (1.28–7.54)**</b>	1.06 (0.65–1.72)
Household financial situation								
Very good	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Good	1.16 (0.91–1.49)	0.68 (0.27–1.71)	0.93 (0.61–1.41)	1.35 (0.96–1.89)	1.04 (0.72–1.50)	1.45 (1.00–2.12)	1.77 (0.53–5.88)	1.51 (0.91–2.53)
Average-to-poor	<b>1.57 (1.15–2.16)**</b>	0.42 (0.09–1.90)	<b>1.63 (1.02–2.60)*</b>	<b>2.07 (1.39–3.07)**</b>	<b>1.66 (1.08–2.55)*</b>	<b>2.38 (1.55–3.64)**</b>	<b>3.76 (1.10–12.83)*</b>	<b>2.11 (1.18–3.78)*</b>

**Table 2.** Association between socio-demographic characteristics and changes in health behaviors due to the COVID-19 pandemic among children and adolescents in Geneva, Switzerland, 2022. \* for p-values < 0.05, \*\* < 0.01. Results are adjusted odds ratios (aOR) and 95% confidence intervals (95% CI) from generalized estimating equations for multinomial response adjusted for age and sex, with *unchanged* as reference category. Analyses performed on complete cases. <sup>a</sup> Adjusted for sex only <sup>b</sup> Adjusted for age only.

health behaviors and other health-related dimensions. This gap highlights the need to establish such studies as an observatory of children's health over time and as a baseline to examine trends following major societal events.

This report suggests that a significant proportion of children and adolescents does not adhere to health behavior recommendations in Switzerland. The COVID-19 pandemic potentially exacerbated existing patterns for older and disadvantaged children, although most children did not experience lifestyle changes. Future research should focus on understanding the reasons for this heterogeneity to identify protective factors. These insights could guide the design of tailored interventions for youth at risk of unhealthier behaviors, helping to reduce the identified social disparities. Specifically, maintaining a routine and spending time outdoors were related to a more active lifestyle during the pandemic<sup>34</sup>. Drawing on these findings, policymakers and schools should prioritize access to quality green spaces and provide affordable, convenient curricular and extracurricular activities. Additionally, interventions could promote parental awareness regarding the benefits of structured routines for children. This is crucial given the importance of lifestyle on the physical and mental health of young people, and their positive impact over the lifecourse<sup>1</sup>.

## Methods

Cross-sectional data was drawn from two studies with similar recruitment and data collection methods: the SEROCOVID-KIDS cohort and a COVID-19 seroprevalence study<sup>35</sup> whose enrollments took place between December 2021 and June 2022. In both studies, children's inclusion criteria were (1) to be aged between 6 months and 17 years old, (2) to live in the canton of Geneva, Switzerland, and (3) to have been (or have a sibling) selected from random samples of the Geneva population, or to be part of the household of a randomly selected individual for previous studies conducted by our research group. The current analysis focused on participants aged between 3 and 17 years, for whom data on pandemic-related changes in health behaviors were collected. The Geneva Cantonal Commission for Research Ethics approved the studies (IDs 2020 – 00881 & 2021 – 01973) and all methods were performed in accordance with the relevant guidelines and regulations. Written informed consent was obtained from participants parent's or legal guardians, as well as from adolescents aged 14 years or older.

Upon enrollment, between December 2021 and June 2022, one referent parent (or caregiver) per household was asked to estimate their children's current recreational screen time, sleep duration, physical activity, and time spent in green spaces on week and weekend days, as well as whether they noticed lasting changes in these dimensions due to the pandemic (e.g. "In your opinion, has the pandemic had a lasting impact on the

amount of time the child spends on screen for recreational activities?” Responses: “yes, it increased”, “yes, it decreased”, “No, it did not change”). Adolescents aged 14 and above self-reported their screen behaviors. Questions were developed by the research team and reviewed by an expert in survey design (Supplementary Table 2). Adherence to health behavior recommendations was assessed using age-specific thresholds from the World Health Organization<sup>36,37</sup> or when not available, from the Canadian 24-Hour Movement Guidelines<sup>38</sup>. Specifically, children aged 3–4 years who engaged in at least 90 min of physical activity per day, and those aged 5 years or older who engaged in at least 60 min per day, were considered to adhere to the recommendations for physical activity. Screen time recommendations were met if daily screen use was one hour or less for 3–4 years old children and two hours or less for older children. Sleep duration was deemed adequate if it ranged from 10 to 13 h per day for children aged 3–4 years, 9 to 11 h for those aged 5–13 years, and 8 to 10 h for adolescents aged 14–17 years. Tertiles differentiating between average to high and low time spent in green spaces were used, as no guidelines exist for this behavior (Supplementary Table 2). Demographic and socio-economic characteristics such as age and sex of children, household financial situation (“very good”, “good”, “average-to-poor”), parents’ country of birth (“at least one parent born in Switzerland”, “parents born outside of Switzerland”) and highest educational level (“college or higher”, “lower than college”) were included as potential correlates.

Regarding the first study aim, the overall prevalence of children not meeting behavior recommendations for screen time, physical activity, time spent in green spaces, and sleep duration was weighted according to the Geneva population’s age and sex distribution<sup>39</sup>. Time spent engaging in health behaviors according to demographic and socio-economic characteristics (age, sex, parents’ birth country, parents’ highest education, household financial situation) and the corresponding non-adherence to recommendations were estimated with marginal prediction from age- and sex-adjusted regressions. To address the second aim, separate analyses were conducted to assess the association between each demographic and socio-economic characteristic and adherence to the recommendations for each behavior. Generalized estimating equations (GEE) adjusted for age and sex (and physical limitations for physical activity) and following a binomial distribution were estimated with the R *geepack* package<sup>40</sup> to account for the household clustering of participants, as some children were siblings. An interaction term was added between age and each of financial situation, parental education, and parental country of birth to capture how the associations with these factors vary across the wide age range under study. Regarding the third aim, demographic and socio-economic correlates of changes in health behaviors due to the pandemic were modelled with age- and sex-adjusted multinomial GEE with *no change* as the reference category using the R *multgee* package<sup>41</sup>. This enabled the identification of specific determinants of both improved and impaired health behaviors, compared to no change. All analyses relied on complete cases.

## Data availability

The dataset related to the present analyses is available for sharing, upon reasonable request to the corresponding author.

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## References

- Saunders, T. J. et al. Combinations of physical activity, sedentary behaviour and sleep: Relationships with health indicators in school-aged children and youth1. *Appl. Physiol. Nutr. Metab.* **41**, 266–282 (2016).
- Sampasa-Kanyinga, H. et al. Combinations of physical activity, sedentary time, and sleep duration and their associations with depressive symptoms and other mental health problems in children and adolescents: A systematic review. *Int. J. Behav. Nutr. Phys. Activity.* **17**, 72 (2020).
- Kharel, M. et al. Impact of COVID-19 pandemic lockdown on movement behaviours of children and adolescents: A systematic review. *BMJ Glob Health.* **7**, e007190 (2022).
- Madigan, S., Eirich, R., Pador, P., McArthur, B. A. & Neville, R. D. Assessment of changes in child and adolescent screen time during the COVID-19 pandemic: A systematic review and Meta-analysis. *JAMA Pediatr.* **176**, 1188–1198 (2022).
- Neville, R. D. et al. Global changes in child and adolescent physical activity during the COVID-19 pandemic: A systematic review and Meta-analysis. *JAMA Pediatr.* **176**, 886–894 (2022).
- Richter, S. A., Ferraz-Rodrigues, C., Schilling, L. B., Camargo, N. F. & Nunes, M. L. Effects of the COVID-19 pandemic on sleep quality in children and adolescents: A systematic review and meta-analysis. *J. Sleep Res.* **32**, e13720 (2022).
- Wunsch, K., Kienberger, K. & Niessner, C. Changes in physical activity patterns due to the Covid-19 pandemic: A systematic review and Meta-Analysis. *Int. J. Environ. Res. Public Health.* **19**, 2250 (2022).
- Cascini, F. et al. A cross-country comparison of Covid-19 containment measures and their effects on the epidemic curves. *BMC Public Health.* **22**, 1765 (2022).
- Coronavirus Federal Council extends COVID certificate requirement and launches consultation on new entry rules. <https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-85035.html>
- Green pass. informazioni utili (Aggiornato 07 Gennaio 2022). *Informa Famiglie e Bambini* <https://www.informafamiglie.it/news/news-articoli-su-famiglie-e-bambini/2021/green-pass-informazioni-utili>
- Pass sanitaire. toutes les informations utiles. <https://www.economie.gouv.fr/tousanticovid-signal-cahier-rappel-numerique>
- Wolch, J. R., Byrne, J. & Newell, J. P. Urban green space, public health, and environmental justice: the challenge of making cities ‘just green enough’. *Landsc. Urban Plann.* **125**, 234–244 (2014).
- Camerini, A. L., Albanese, E. & Marciano, L. The impact of screen time and green time on mental health in children and adolescents during the COVID-19 pandemic. *Computers Hum. Behav. Rep.* **7**, 100204 (2022).
- Andrade, C., Gillen, M., Molina, J. A. & Wilmarth, M. J. The social and economic impact of Covid-19 on family functioning and Well-Being: Where do we go from here? *J. Fam Econ. Iss.* **43**, 205–212 (2022).
- Aguilar-Farias, N. et al. Sociodemographic predictors of changes in physical activity, screen time, and sleep among toddlers and preschoolers in Chile during the COVID-19 pandemic. *Int. J. Environ. Res. Public Health.* **18**, 176 (2021).
- Zhu, S., Zhuang, Y. & Ip, P. Impacts on children and adolescents’ lifestyle, social support and their association with negative impacts of the COVID-19 pandemic. *Int. J. Environ. Res. Public Health.* **18**, 4780 (2021).
- Richard, V. et al. Social determinants of the health behaviours of children and adolescents during the COVID-19 pandemic. *Popul Med* **5**, (2023).

18. Hale, T. et al. A global panel database of pandemic policies (Oxford COVID-19 government response Tracker). *Nat. Hum. Behav.* **5**, 529–538 (2021).
19. Peralta, G. P. et al. Lifestyle behaviours of children and adolescents during the first two waves of the COVID-19 pandemic in Switzerland and their relation to Well-Being: an observational study. *International J. Public Health* **67**:1604978, (2022).
20. Sterdt, E., Liersch, S. & Walter, U. Correlates of physical activity of children and adolescents: A systematic review of reviews. *Health Educ. J.* **73**, 72–89 (2014).
21. Stierlin, A. S. et al. A systematic review of determinants of sedentary behaviour in youth: A DEDIPAC-study. *Int. J. Behav. Nutr. Phys. Activity.* **12**, 133 (2015).
22. Olds, T., Blunden, S., Petkov, J. & Forchino, F. The relationships between sex, age, geography and time in bed in adolescents: A meta-analysis of data from 23 countries. *Sleep Med. Rev.* **14**, 371–378 (2010).
23. Poulain, T. et al. Associations between Socio-Economic status and child health: findings of a large German cohort study. *Int. J. Environ. Res. Public Health.* **16**, 677 (2019).
24. Mielke, G. I., Brown, W. J., Nunes, B. P., Silva, I. C. M. & Hallal, P. C. Socioeconomic correlates of sedentary behavior in adolescents: Systematic review and Meta-Analysis. *Sports Med.* **47**, 61–75 (2017).
25. Zhang, Z. et al. Correlates of sleep duration in early childhood: A systematic review. *Behav. Sleep. Med.* **19**, 407–425 (2021).
26. West, P. Health inequalities in the early years: is there equalisation in youth? *Soc. Sci. Med.* **44**, 833–858 (1997).
27. O'Connor, S. & Bélanger-Gravel, A. team, for the iCARE study. Social determinants of long-term reported changes in physical activity and healthy eating during the COVID-19 pandemic in Canada: multiple cross-sectional surveys analysis from the iCARE study. *Appl. Physiol. Nutr. Metab.* <https://doi.org/10.1139/apnm-2023-0206> (2023).
28. Zajacova, A., Jehn, A., Stackhouse, M., Denice, P. & Ramos, H. Changes in health behaviours during early COVID-19 and socio-demographic disparities: A cross-sectional analysis. *Can. J. Public Health.* **111**, 953–962 (2020).
29. Gropper, H., John, J. M., Sudeck, G. & Thiel, A. The impact of life events and transitions on physical activity: A scoping review. *PLOS ONE.* **15**, e0234794 (2020).
30. Richard, V. et al. Impact of the COVID-19 pandemic on children and adolescents: determinants and association with quality of life and mental health—a cross-sectional study. *Child Adolesc. Psychiatry Mental Health.* **17**, 17 (2023).
31. Galea, S. & Tracy, M. Participation rates in epidemiologic studies. *Ann. Epidemiol.* **17**, 643–653 (2007).
32. OCSTAT - Office cantonale de la statistique du canton de Genève. Population résidante selon le sexe, le groupe d'âges et le plus haut niveau de formation achevée, de 2016 à 2020. (2022).
33. Sithole, F. & Veugelers, P. J. Parent and child reports of children's activity. *Statistics Canada, Catalogue no. 82-003-XPE, Health Reports* 19, (2008).
34. Kovacs, V. A. et al. Physical activity, screen time and the COVID-19 school closures in Europe – An observational study in 10 countries. *Eur. J. Sport Sci.* **22**, 1094–1103 (2022).
35. Zaballa, M. E. et al. Seroprevalence of anti-SARS-CoV-2 antibodies and cross-variant neutralization capacity after the Omicron BA.2 wave in Geneva, Switzerland: a population-based study. *The Lancet Reg. Health - Europe* **24**, (2023).
36. World Health Organization. WHO guidelines on physical activity and sedentary behaviour. (2020).
37. World Health Organization. Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age. (2019).
38. Canadian Society for Exercise Physiology. Canadian 24-Hour Movement Guidelines for the Children and Youth (5–17 years): An Integration of Physical Activity, Sedentary Behaviour, and Sleep. (2016).
39. OCSTAT - Statistique cantonale de la population. Pyramide des âges de la population résidante du canton de Genève, selon l'origine et le sexe, à fin 2021. (2022).
40. Højsgaard, S., Halekoh, U. & Yan, J. The R package geepack for generalized estimating equations. *J. Stat. Softw.* **15**, 1–11 (2006).
41. Touloumis, A. R. Package multgee: A generalized estimating equations solver for multinomial responses. *J. Stat. Softw.* **64**, 1–14 (2015).

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## Author contributions

All authors contributed to the study conception and design. Material preparation and data collection were performed by V.R., R.D., E.L., A.L., H.B., M-E. Z., J.L. and S.S. R.P.B., K.M.P-B., I.G. and S.S. supervised the study. Analyses were performed by V.R. who also wrote the first draft of the manuscript. All authors read and critically revised the manuscript, and approved the final version.

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## Declarations

## Competing interests

The authors declare no competing interests.

## Additional information

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