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Original Article

Reduced Physical Activity During COVID-19 in Children With Congenital Heart Disease: A Longitudinal Analysis

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ABSTRACT

Background: Coronavirus disease 2019 (COVID-19) was associated with a reduction in physical activity in children with congenital heart disease (CHD) in early 2020. Given the increased cardiovascular risk of this population, optimizing cardiovascular health behaviour is important. The aim of the study is to determine how the ongoing COVID-19 pandemic has impacted longitudinal physical activity measures in children with CHD.

Methods: As part of a prospective cohort study, children and adolescents aged 9-16 years old with moderate-to-complex CHD were recruited from British Columbia Children's Hospital and partnership clinics across British Columbia and the Yukon territory. Daily step counts were measured continuously over 3 years (2018-2021) with Fitbit Charge 2. School status during the COVID-19 pandemic was assessed with parent- or self-report survey.

Results: A total of 102, 114, and 93 participants had valid Fitbit data during 2018, 2019, and 2020, respectively. There was a significant reduction in the annual mean step count for 2020 (8225 ± 4328

RÉSUMÉ

Contexte : Au début de l'année 2020, la maladie à coronavirus 2019 (COVID-19) a été associée à une diminution de l'activité physique chez les enfants présentant une cardiopathie congénitale. Compte tenu du risque cardiovasculaire accru chez ces patients, il importe d'optimiser les comportements en matière de santé cardiovasculaire. Cette étude visait à évaluer les répercussions de la pandémie actuelle de COVID-19 sur les mesures longitudinales de l'activité physique auprès d'enfants présentant une cardiopathie congénitale.

Méthodologie : Pour cette étude de cohorte prospective, des enfants et des adolescents de 9 à 16 ans atteints de cardiopathie congénitale modérée ou complexe ont été recrutés au British Columbia Children's Hospital ainsi que dans les cliniques partenaires de la Colombie-Britannique et du Yukon. Le nombre de pas quotidiens a été compté en continu pendant trois ans (2018-2021) à l'aide d'un appareil Fitbit Charge 2. Les enfants ou leurs parents ont indiqué, à l'aide d'un sondage, s'ils allaient à l'école ou non pendant la pandémie de COVID-19.

In March 2020, the World Health Organization declared the coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) a global pandemic. Public health measures to prevent the spread of COVID-19 were then instituted in British Columbia (BC). These restrictions, such as school and park closures and recommendations to stay at home, have limited children's ability to engage in physical activity.¹ We found reduced levels of physical activity in children with congenital heart disease (CHD) early in the COVID-19 pandemic.² However, there is a paucity of data on the long-term effects of the pandemic on physical activity levels in children, including those with CHD.

Physical activity is an important determinant for optimizing the long-term cardiovascular health and quality of life in the CHD population, and is a healthy and adaptive coping

strategy during the time of stress.³⁻⁷ Children with CHD are at an increased risk for secondary cardiovascular events and reported lower quality of life compared with their healthy peers.^{8,9} Owing to these physical and mental health benefits of physical activity, it is even more crucial to maintain and promote physical activity participation for this at-risk population as we enter the third year of the pandemic.¹⁰

Physical activity is a modifiable behaviour that tracks from childhood into adulthood.¹¹ As COVID-19 restrictions continuously change, the ongoing impact of COVID-19-related measures on physical activity participation in children with CHD has not yet been described. It is important to understand the changes in physical activity behaviours during the COVID-19 pandemic to aid in the development of physical activity interventions, to promote physical activity if further public health measures should be reintroduced, and to encourage a return to prepandemic physical activity levels.¹² Given the lack of data presently available in the literature, we sought to address this knowledge gap. The aim of this study is to determine the longitudinal impact of the COVID-19 pandemic on physical activity levels and patterns in children with CHD.

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steps) compared with both 2018 (9416 ± 3770 steps) and 2019 (9533 ± 4114 steps) ($P < 0.001$). There was a loss of seasonal variation in physical activity, and reduced levels of physical activity persisted when most children resumed in-person schooling in September 2020.

Conclusions: We demonstrated a significant decrease in physical activity and loss of seasonal patterns in children with CHD during 2020. These findings represent a worsening of the cardiovascular risk profile in children with CHD, who are already at an increased risk of adverse cardiovascular outcomes. Mitigation strategies are needed to optimize the cardiovascular health status of children with CHD as the pandemic persists.

Material and Methods

Data were collected as part of an ongoing prospective cohort study of children and adolescents aged 9-16 years old with moderate-to-severe CHD. Children with CHD diagnosed with coarctation of the aorta, tetralogy of Fallot, transposition of the great arteries, or Fontan circulation were recruited at the British Columbia Children's Hospital Heart Centre in Vancouver or partnership clinics throughout BC and the Yukon from April 2017. For this study we included children enrolled from March 2018 through February 2021. This allowed us to analyze data from 2 years before the onset of the COVID-19 pandemic and the first year of the COVID-19 pandemic. Children were excluded if they had other health conditions that would prevent them from completing the study measures or participating in physical activity. We obtained patient characteristics, such as sex, age, and cardiac diagnosis, from medical charts. The study was approved by the University of British Columbia Research Ethics Board (H17-01233).

Physical activity measurement

Participants were provided a Fitbit Charge 2 (Fitbit Inc, San Francisco, CA) and were asked to wear and sync the device for the duration of the study. We have previously validated the use of commercial activity trackers for quantifying physical activity in children with CHD.¹³ Wristband size and placement were in accordance with manufacturer guidelines. Fitbit data were collected and managed with the use of Research Electronic Data Capture tools hosted at British Columbia Children's Hospital.^{14,15}

In the absence of consensus on wear time validation for commercial trackers in children, we considered a day to be valid if they had at least 1000 steps. Weekly (Monday to Sunday) step counts were calculated by averaging the step counts from all the valid days of each week. We defined meeting physical activity guidelines (60 minutes of moderate-to-vigorous physical activity per day) as $\geq 12,000$ steps per day.¹⁶ Annual step count data for 2018, 2019, and 2020 were taken from March 2018 to February 2019, March 2019 to February 2020, and March 2020 to February 2021, respectively. We defined the seasons as spring (March to May),

Résultats : Des données de l'appareil Fitbit ont été obtenues chez un total de 102, 114 et 93 participants en 2018, 2019 et 2020, respectivement. Une nette réduction du nombre de pas annuel moyen en 2020 (8225 ± 4328 pas) a été constatée par rapport à 2018 (9416 ± 3770 pas) et à 2019 (9533 ± 4114 pas) ($p < 0,001$). Les variations saisonnières de l'activité physique se sont amoindries, et le faible volume d'activité physique a perduré même lorsque la majorité des enfants avaient repris l'école en présentiel, en septembre 2020.

Conclusions : Une nette diminution de l'activité physique et un affaiblissement des variations saisonnières de l'activité physique ont été observés chez les enfants présentant une cardiopathie congénitale en 2020. Ces résultats signifient une aggravation du risque cardiovasculaire que courent ces patients, déjà exposés à un risque accru d'événements cardiovasculaires. Comme la pandémie persiste, des stratégies d'atténuation des risques sont nécessaires pour optimiser la santé cardiovasculaire des enfants présentant une cardiopathie congénitale.

summer (June to August), autumn (September to November), and winter (December to February). We previously demonstrated that levels of physical activity were reduced at the start of the pandemic.² In this analysis, we investigated the longitudinal physical activity patterns in the first year of the COVID-19 pandemic. Differences in weekly average were assessed between 2019 and 2020 to understand how physical activity patterns changed during the COVID-19 pandemic.

School information

School data were collected through a parent- or self-report survey, including the participants' school status from March 2020 onward when public health measures began in BC. Participants were asked if they were (1) not in school, (2) in person full-time, (3) virtual full-time, (4) part-time in-person and part-time virtual, (5) home schooled, or (6) other combinations for the following periods: March to May 2020, June 2020, September to December 2020, and January 2021 onwards. These periods are in accordance with major updates on the public health announcements related to COVID-19 and schools in BC.

Statistical analysis

Descriptive statistics (n [%] or mean \pm standard deviation) were calculated for applicable variables. Distribution of continuous variables was assessed visually. Continuous variables were assessed using 1-way analysis of variance (*post hoc* Bonferroni correction) or Student *t*-tests. Categorical variables were assessed using χ^2 tests. The "lowess" function in R was used to generate a physical activity line of best fit from the weekly Fitbit step counts for each year. Significance was set at $P < 0.05$. All analyses were performed in R (v.4.0.3) using R-studio (v.1.3.1073).

Results

A total of 140 participants were enrolled and had valid Fitbit data during the study period. There were a total of 102 participants for the 2018 (March 2018 to February 2019) period (age 12.1 ± 2.4 , 58 [56.9%] male), 114 participants for the 2019 (March 2019 to February 2020) period (age

Table 1. Sample characteristics

Variables	2018	2019	2020	<i>P</i> value
N	102	114	93	
Age	12.1 ± 2.4	12.6 ± 2.4	13.1 ± 2.5	0.012*
Male	58 (56.9)	61 (53.5)	45 (48.4)	0.492
Diagnosis				
Coarctation of the aorta	28 (27.5)	30 (26.3)	25 (26.9)	0.997
Tetralogy of Fallot	30 (29.4)	32 (28.1)	24 (25.8)	
Transposition of the great arteries	19 (18.6)	23 (20.2)	18 (19.3)	
Fontan circulation	25 (24.5)	29 (25.4)	26 (28.0)	
Step counts	9416 ± 3770	9533 ± 4114	8225 ± 4328	<0.001*
Boys' step counts	10,025 ± 4008	10,508 ± 4529	8970 ± 4412	<0.001*
Girls' step counts	8668 ± 3308	8421 ± 3244	7637 ± 4170	<0.001*
Meet 12,000 steps [†]	15 (14.7)	18 (15.8)	9 (9.7)	0.409

Results are reported as n (%) or mean ± standard deviation.

* Significant difference.

[†] Proposed daily step target to determine if children are meeting physical activity guidelines.¹⁶

12.6 ± 2.4, 61 [53.5%] male), and 93 participants for the 2020 (March 2020 to February 2021) period (age 13.1 ± 2.5, 45 [48.4%] male). Of these, 59 participants wore the Fitbit and provided data through the full 3-year period. There were no significant differences in participant characteristics except for age. Participant characteristics are presented in Table 1.

The annual mean daily step counts in 2018, 2019, and 2020 remained below 12,000 steps per day. There was a significant reduction in the mean step count for 2020 (8225 ± 4328 steps) compared with both 2018 (9416 ± 3770 steps) and 2019 (9533 ± 4114 steps) (*P* < 0.001). The reduction was significant for both males (Table 1, *P* < 0.001) and females (Table 1, *P* < 0.001). A minority of participants (15%, 16%, and 10% in 2018, 2019, and 2020, respectively) met the recommended mean daily step goal of >12,000 steps per day (Table 1, *P* = 0.409). Weekly Fitbit step count line of best fits for 2018, 2019, and 2020, taken over a 1-year period from the first week of March (week 1) to the last week of February (week 52), are shown in Figure 1. Physical activity trends in 2018 and 2019 were comparable, and both clearly illustrated seasonal peaks (during the spring and fall) and dips (during the summer and winter) in physical activity (Fig. 1). In 2020, step counts began to decline during the initial phase of the COVID-19 pandemic, remained low throughout the remainder of the year, and did not show the seasonal variation in physical activity observed in 2018 and 2019. Mean step counts between matched weeks of 2019 and 2020 were significantly reduced in the latter for 19 of 52 weeks (36.5% of the year, Supplemental Table S1). A total of 77 participants (82.8%) responded to the school status survey. At the beginning of the pandemic (March to May 2020), 72% of participants reported attending school only virtually (Table 2). When the new school year started in the fall (September 2020), 58% of participants were attending school in-person full-time (Table 2). The reduction in levels of physical activity persisted even though in-person school had resumed for most children by fall 2020 (Fig. 1).

Discussion

COVID-19-related restrictions have had widespread adverse impacts on physical activity behaviour in children with CHD. To our knowledge, this is the first study to provide objective and continuous data on physical activity

patterns before and during the COVID-19 pandemic in this population. Our study demonstrated a significant decrease in physical activity levels and loss of seasonal patterns in children with CHD throughout 2020 and early 2021. This reduction in physical activity is temporally linked to COVID-19-related measures and persisted even once most participants had returned to in-person schooling.

Decline in levels of physical activity

We previously demonstrated that the step counts of children with CHD began to decrease in the early March of 2020 when COVID-19 was declared a pandemic by the World Health Organization and public health measures to prevent the spread of COVID-19 were instituted in BC and persisted through the following early weeks of the pandemic.² Comparable reductions in physical activity have been documented by other studies in children and adolescents worldwide.^{1,17–21} With the use of commercial activity trackers, we were able to objectively track and model physical activity patterns in this cohort before and during the COVID-19 pandemic. The mean step counts remained below the recommended 12,000 steps per day (approximation of the Canadian physical activity guidelines)¹⁶ in all 3 years of the study and were significantly reduced in 2020, as compared with previous years. This significant decline in physical activity during COVID-19 was present in both male and female participants and persisted throughout the year. Guerrero et al.²² demonstrated that during the pandemic, only 18.2% of healthy Canadian children met physical activity recommendations. In our CHD cohort, only 9.7% met the recommended step counts in 2020 as compared with 15.8% in 2019. The overall reduction in levels of physical activity in children with CHD is particularly concerning given the increased cardiovascular risk in this population.⁸

The initial reduction in physical activity was felt to be due to school closures and cancellation of school-based and community-based physical activity programmes. Older children (>9 years of age), like those in our cohort, preferentially engage in organized physical activity (eg, physical education class, sports teams).^{23,24} The continuous tracking of physical activity during 2020 demonstrated 2 important points: (1) there is a loss of seasonal patterns in physical activity and (2) the absence of school-facilitated physical activity when school

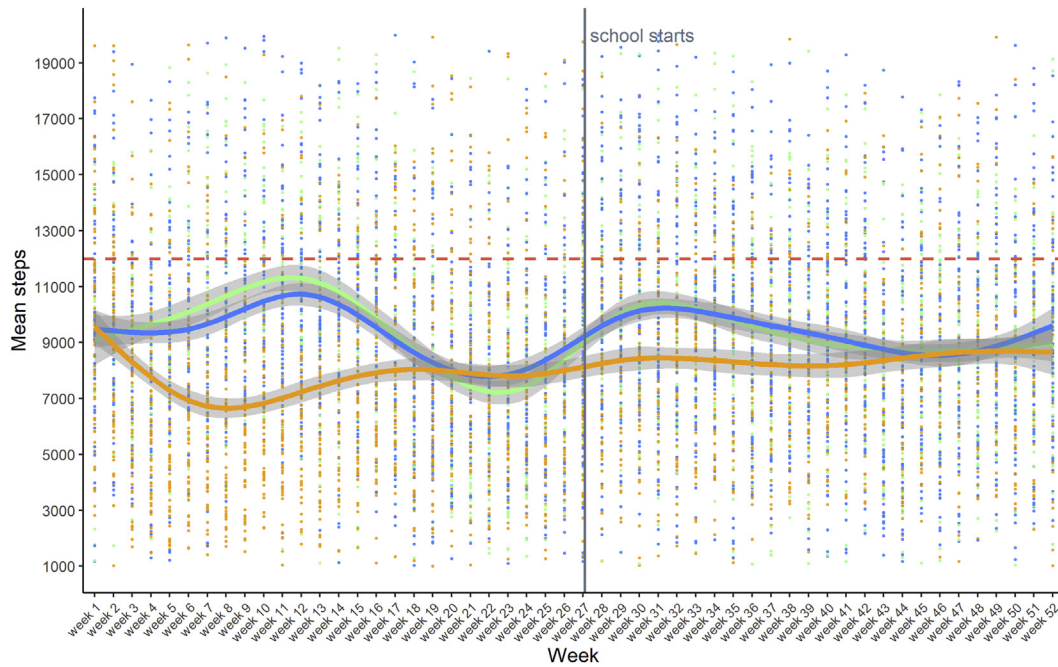


Figure 1. Weekly Fitbit step counts in 2018, 2019, and 2020. Weeks run Monday to Sunday. Week 1 began on March 5, 2018, March 4, 2019, and March 2, 2020, in 2018, 2019, and 2020, respectively. The **dots** (green = 2018; blue = 2019; orange = 2020) indicate individual participants’ mean weekly step counts. The **lines** illustrate the line of best fit for each year. The **grey shading** indicates the standard error. The **red dashed line** is the target 12,000 steps per day, which approximates the Canadian physical activity guidelines of 60 minutes per day of moderate-to-vigorous physical activity.¹⁶ The **grey vertical line** (week 27) is the first week of September when school started.

was back in session. We demonstrated that activity levels remained blunted throughout the COVID-19 pandemic, regardless of season. Furthermore, our data demonstrated that even when the majority of the participants were back in school in-person, the reduced level of physical activity continued into the school year, which could portend negative long-term impacts of the pandemic on physical activity behaviours. Typically, reduced physical activity levels observed during summer vacation are followed by increased physical activity when students return to school.^{25,26} Schools are well known to provide opportunities and facilities for physical activity through physical education class, recess, and structured sport teams.^{27,28} Our data suggest that despite the prior beneficial effect of school on physical activity participation, the extended period of inactivity since March 2020 due to COVID-19-related restrictions may have adversely affected physical activity behaviour in children with CHD on resumption of school. Alternatively, the facilitating influences of schools on physical activity may have been altered by the COVID-19 pandemic.

Physical activity is associated with the physical and psychological health of children with CHD

Physical inactivity may have enormous consequences for the overall physical and psychological health of children with CHD in the long term.¹⁰ It is well established that children with CHD are at an increased risk for secondary cardiovascular events.⁸ Those who are more physically active are shown to have better vascular function, partially mitigating their cardiovascular risk.²⁹ The extended reduction in levels of physical activity in 2020 is particularly concerning as physical activity is a modifiable behaviour that tracks into adulthood.¹¹ If COVID-19 precautions continue to blunt the physical activity levels in children with CHD, this could have long-term implications given the importance of childhood and adolescence in establishing health behaviour patterns. The decline in physical activity during COVID-19, in conjunction with the observed increased sedentary behaviour, screen time, and worsening dietary intake during the pandemic, may increase the risk of developing obesity.³⁰ It has been reported in

Table 2. School status during the COVID-19 pandemic

	March to May 2020	June 2020	September to December 2020	January 2021 onwards
Not in school	2 (2.2)	4 (4.3)	2 (2.2)	2 (2.2)
In-person full-time	5 (5.3)	6 (6.4)	54 (58.0)	57 (61.3)
Virtual full-time	67 (72.0)	58 (62.4)	8 (8.6)	7 (7.5)
Part-time in-person and part-time virtual	1 (1.1)	7 (7.5)	10 (10.7)	9 (9.6)
Home schooled	0 (0)	0 (0)	2 (2.2)	2 (2.2)
Other combinations	2 (2.2)	2 (2.2)	1 (1.1)	0 (0)

Results are reported as n (%).

another cohort of children with CHD that the decrease in physical activity is accompanied by an increase in their body mass index.³¹ Increased body mass and adiposity have been associated with arterial stiffening,³² a surrogate marker for future adverse cardiovascular outcomes. Furthermore, physical activity is positively associated with self-efficacy, higher perceived health status, and better health-related quality of life in children with CHD,^{33–35} who have reported lower quality of life compared with their healthy peers.⁹ With COVID-19-related restrictions, cognitive performance among children has drastically declined.³⁶ Children also reported significantly lower health-related quality of life, more mental health problems, and higher anxiety levels.^{37,38} Therefore, it is even more imperative to encourage patients with CHD to be physically active to combat the short-term stress induced by the pandemic and the long-term consequences of reduced physical activity to their physical and psychological health.

Future directions

Many children have experienced a disturbance in learning, socialization, and physical activity during the COVID-19 pandemic.³⁹ Although there are recommendations to maintain an active lifestyle during the pandemic, none are geared towards children with CHD.⁴⁰ As COVID-19-related measures continue, further study is required to identify factors that contribute to physical activity reduction as well as determinants for maintaining physical activity in light of COVID-19 and related restrictions. It is also important to identify effective strategies to intervene on the negative behaviour changes imposed by public health measures and restrictions. There is a need for physical activity promotion for children with CHD, especially among physicians working with this vulnerable cohort. Physical activity recommendations and counselling from physicians play an important factor in guiding in patients' and families' decisions to adopt an active lifestyle.⁴¹ As there is evidence that physical activity intervention in the CHD population leads to improvement in physical activity and cardiorespiratory fitness,⁴² personalized and supervised physical activity counselling or intervention programmes delivered through technology platforms (eg, Telehealth) should be implemented and their impact evaluated.⁴³ Such information will enable health care providers and policy makers to identify ways to support and promote physical activity in this population.

Strengths and limitations

One of the main strengths of our study is the longitudinal objective physical activity data from 2018 to 2021, which allowed us to clearly track and compare the physical activity levels and patterns before and during the pandemic. To the best of our knowledge, ours is the first study to demonstrate the longitudinal impact of the COVID-19 pandemic on physical activity patterns in children with CHD. Some potential limitations of this study should be considered. First, the use of physical activity trackers does not reflect physical activity mode or intensity, and some activities may not be accurately measured by commercial wrist worn devices. In addition, because of the nature of the ongoing cohort study

limited to children with CHD, generalizability of these data to children without heart disease may be limited.

Conclusions

COVID-19-imposed restrictions have exacerbated the problem of physical inactivity in children and adolescents with CHD. Considering the health risks associated with low levels of physical activity, which are amplified in children with CHD, clinicians, policy makers, and other stakeholders need to consider physical activity intervention strategies to address the long-term impacts of the pandemic. Encouraging physical activity to promote physical and mental well-being in this vulnerable population is needed to support optimal cardiovascular health and encourage positive health behaviours that track into adulthood.

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Ethics Statement

The research has adhered to UBC research board ethical guidelines.

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Disclosures

The authors have no conflicts of interest to disclose.

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Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Pediatric and Congenital Heart Disease* at <https://www.cjpc.ca/> and at <https://doi.org/10.1016/j.cjpc.2022.05.006>