



Activity During the COVID-19 Pandemic in Children with Cardiac Rhythm Management Devices

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Abstract

Decreased physical activity is associated with cardiovascular, metabolic and mental health disease. While decreases in physical activity during the COVID-19 pandemic have been described in the general population, there is a paucity of data regarding children with underlying cardiovascular disease. We hypothesized there would be a decrease in physical activity at the onset of the COVID-19 pandemic. Performed a single-center, retrospective cohort study of children aged < 19 years with cardiac rhythm management devices. Patients were included if they had device-measured physical activity data from > 80% of dates from February 3, 2020 through June 30, 2020. Patients with significant neurologic/neuromuscular disease were excluded. We identified 144 patients with a median age of 15.4 years. 47% were female. 34% had congenital heart disease, 20% had cardiomyopathy, 19% had an inherited arrhythmia syndrome and 5% had atrioventricular block without congenital heart disease. 47% of patients had an implantable loop recorder, 29% had a permanent pacemaker and 24% had an implantable cardioverter-defibrillator. We observed a significant decrease in device-measured physical activity from baseline (February 3–March 9), with up to a 21% decrease in physical activity during mid-March through early May. Activity levels returned to pre-pandemic levels in June. Physical activity sharply declined in children with cardiac rhythm management devices at the onset of the COVID-19 pandemic. These data highlight the importance of finding strategies to maintain physical activity during the current pandemic and future public health crises.

Keywords Pediatrics · Physical activity · Congenital heart disease · Obesity

Abbreviations

COVID-19	Coronavirus disease 2019
CRMDs	Cardiac rhythm management devices
ICD	Implantable cardioverter-defibrillator
CHD	Congenital heart disease
BMI	Body mass index
SIP	Shelter in place
WHO	World Health Organization

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has had profound effects on the lives of billions across the globe since its onset in December of 2019. In order to combat the

outbreak and slow the spread of disease, social distancing guidelines were implemented and, in many places, shelter in place orders were put in place. Investigators have shown that physical activity declined after the onset of the COVID-19 pandemic in both pediatric and adult populations [1–3].

Even prior to the onset of the COVID-19 pandemic, inadequate physical activity was common in the USA with less than one-quarter of school-aged children participating in the recommended 60 min of physical activity daily [4]. Importantly, consequences of decreased physical activity include increased risk of developing cardiovascular and metabolic disease [5–9]. Avoidance of these conditions is likely to be of increased importance in individuals with underlying heart disease.

Many cardiac rhythm management devices (CRMDs) are capable of collecting device-measured physical activity data by utilizing internal accelerometers or detectors of thoracic impedance to detect changes in patient movement which are translated into electronic data and made available to the clinicians managing patients with these devices using

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proprietary algorithms [10]. Prior studies comparing device-measured physical activity from implanted CRMDs against either previously validated external accelerometers or 6-min walk tests have shown moderate correlation [11–15].

There is a paucity of data regarding how the COVID-19 pandemic and associated restrictions have affected children with cardiovascular disease. We hypothesized there would be a decrease in physical activity in this population related to the onset of the COVID-19 pandemic and the associated “shelter-in-place” (SIP) order in the state of Massachusetts issued on March 24, 2020.

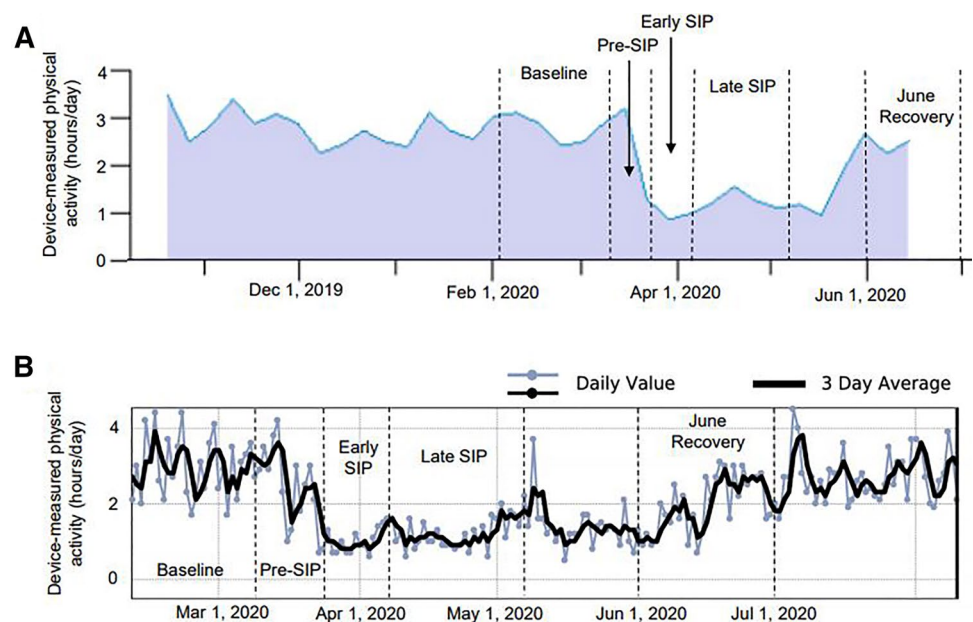
Methods

We performed a single-center, retrospective cohort study of children and adolescents aged less than 19 years and followed at Boston Children’s Hospital with CRMDs including permanent pacemakers, implantable cardioverter-defibrillators (ICDs), and implantable loop recorders capable of tracking daily activity level. Patients were included if they had device-measured physical activity data from > 80% of dates across the study period from the start of February 3, 2020 through June 30, 2020. Patients may have had data from < 80% of the study period if their CRMD was implanted or explanted during the study period or if transtelephonic transmissions or device checks were not performed routinely. Patients with neurologic and neuromuscular diseases expected to have a significant impact on physical activity such as hypoxic ischemic encephalopathy or skeletal myopathy were excluded. This study was approved by the Institutional Review Board of our institution with a waiver of informed consent.

Device-measured physical activity data were abstracted from databases kept by the CRMD manufacturers (Medtronic Inc., Minneapolis, Minnesota and Boston Scientific, Natick, Massachusetts) or CRMD reports available through our internal electronic medical record in hours of device-measured physical activity per day. Some devices included in this study had a maximum daily device-measured physical activity of 8 h. We additionally collected information regarding the type of CRMD implanted and demographic information including age, sex, body mass index (BMI), and state of residence. We also collected cardiovascular disease-specific information including the nature of cardiovascular disease which we broadly classified as structural congenital heart disease (CHD), cardiomyopathy, atrioventricular conduction disturbances without associated CHD, and inherited arrhythmia syndromes. Patients who did not have a disease process described by any of the aforementioned categories were categorized as ‘other’.

The study period was divided into five time periods defined as follows: Baseline (February 2 through March 9), Pre-SIP (March 10 through March 23), Early SIP (March 24 through April 6), Late SIP (April 7 through May 4) and June (June 1 through June 30) (Fig. 1). These dates were chosen to correspond with Massachusetts social distancing guidance to assess changes in physical activity before and after SIP orders were given. The primary outcome was hours per day of device-measured physical activity in each time period compared to the baseline period and this relationship was assessed using the paired Student’s *t* tests. We compared the proportion of patients with < 2 h of daily device-measured physical activity at baseline to each of the subsequent time periods using Chi-squared tests. We also performed a sub-analysis of children less than 6 years of age using Wilcoxon

Fig. 1 Examples of device-measured physical activity reports with characteristic trends: **A** Medtronic implantable loop recorder, **B** Boston Scientific ICD



signed-rank tests. We compared differences in device-measured physical activity in patients with elevated body mass index (BMI; BMI \geq 85thile) with those with non-elevated BMIs, between male and female patients and between Massachusetts residents and non-Massachusetts New England residents using Wilcoxon rank-sum tests. Finally, in the

subset of patients with activity data available from February through June in 2019, 2020 and 2021, we compared 2020 levels of activity with 2019 and 2021 levels of activity. We also compared activity levels from the baseline period in 2019 with the subsequent 2019 time periods and activity levels from the baseline period in 2021 with subsequent 2021 time periods using paired Student's *t* tests. Statistical analyses were performed using Stata 16 statistical software (Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC).

Table 1 Patient characteristics

Patients	144
Female sex	67 (47)
Age in years	15.4 (11.3–17.5)
State of residence	
Massachusetts resident	86 (60)
Non-Massachusetts New England resident	40 (28)
Non-New England resident	18 (12)
*BMI percentile	62 (29–87)
*Elevated BMI (\geq 85 th ile)	47 (35)
Underlying cardiovascular disease	
Congenital heart disease (CHD)	49 (34)
Cardiomyopathy	29 (20)
Inherited arrhythmia syndrome	27 (19)
Atrioventricular block without CHD	7 (5)
Other	32 (22)
Type of cardiac rhythm management device	
Implantable loop recorder	68 (47)
Permanent pacemaker	41 (29)
Implantable cardioverter-defibrillator	35 (24)

Categorical data presented as *n* (%)

Continuous data presented as median (interquartile range)

*BMI percentile data available for 134 patients

Results

We identified 180 patients who met inclusion criteria. Of this group, 30 had insufficient device-measured physical activity data and six had significant neurologic or neuromuscular comorbidities and were excluded. This left 144 patients whose characteristics are summarized in Table 1. We observed statistically significant declines in device-measured physical activity from baseline in each of the subsequent time periods beginning in the pre-SIP period through the late SIP period with recovery of activity in June (Fig. 2A). The maximal decline in device-measured physical activity occurred in the early SIP period with a median 21% decrease in activity from baseline levels (interquartile range 2–37%; $p < 0.001$). There was a statistically significant increase in the number of patients with < 2 h of device-measured physical activity per day in each period compared to the baseline period (Fig. 2B). In a sub-analysis of children < 6 years of age, we found no statistically significant

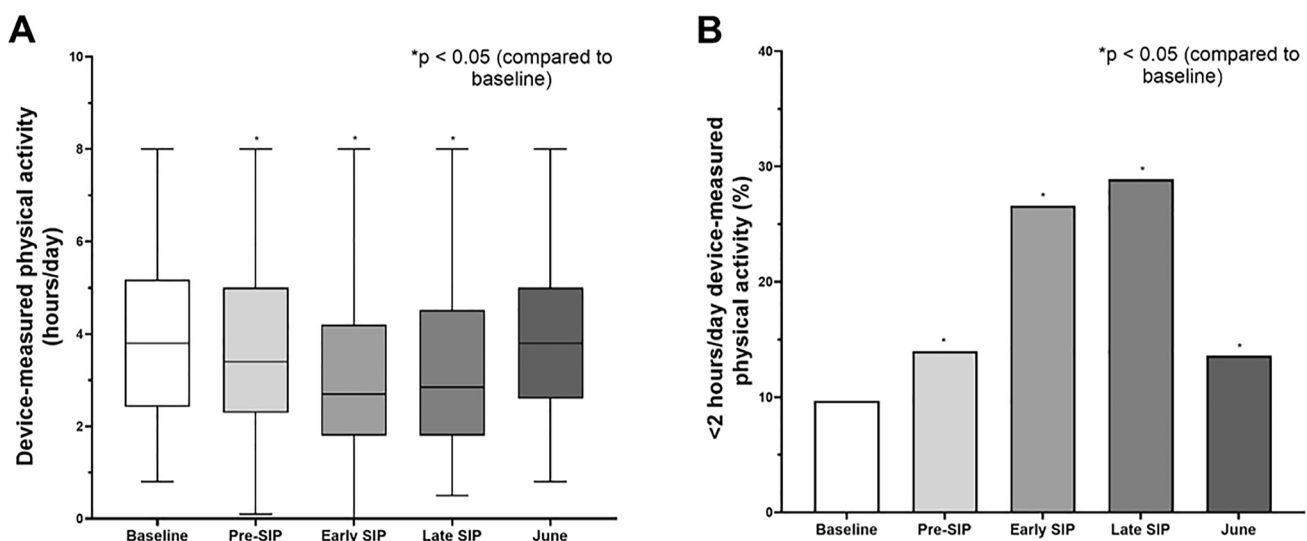


Fig. 2 **A** Device-measured physical activity during the study period. **B** Percentage of children with < 2 h/day of device-measured physical activity

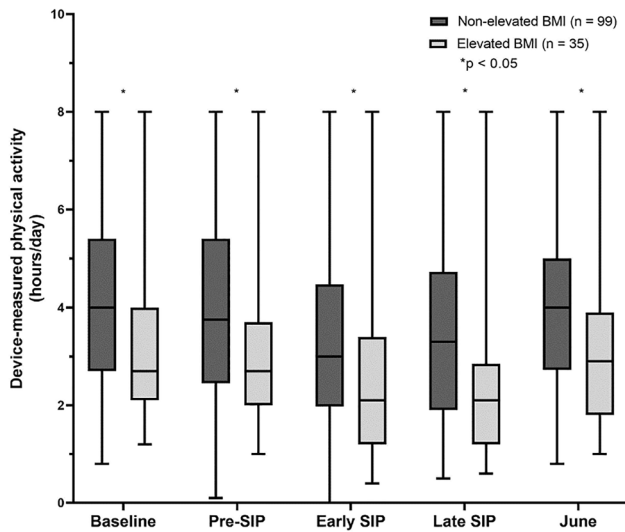


Fig. 3 Differences in device-measured physical activity in children with elevated and non-elevated BMI during the study period

change in device-measured physical activity from baseline aside from an increase in June.

Children and adolescents who had elevated BMI were statistically significantly less active than those who had non-elevated BMI at baseline and during every subsequent time period (Fig. 3). There was no statistically significant difference in device-measured physical activity in males compared to females and no statistically significant difference in device-measured physical activity between residents of Massachusetts and residents of other New England states during any time period.

A subset of patients additionally had activity data available from the same time periods in 2019 and 2021 (Fig. 4). These patients were statistically significantly less active in 2020 compared to the corresponding time periods in 2019 in each of the study periods. They were also statistically significantly less active in 2020 compared to 2021 in early SIP, late SIP, and June and were also less active in the pre-SIP period, though this narrowly missed statistical significance ($p=0.07$). There were no statistically significant differences in activity levels between 2019 and 2021. In 2019 and 2021, these patients exhibited no statistically significant change in activity from baseline during any of the subsequent time periods aside from an increase in activity during June during both years.

Discussion

In this study of activity in children and adolescents with CRMDs at the onset of the COVID-19 pandemic in the USA, we found statistically significant declines in device-measured

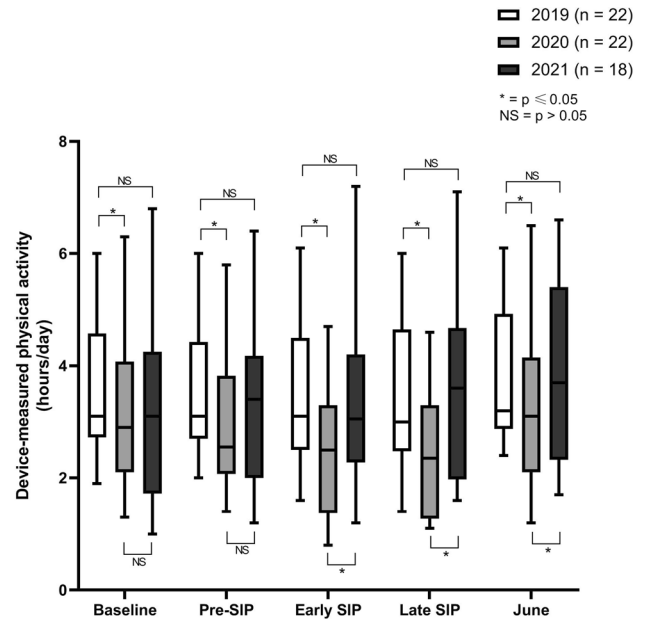


Fig. 4 Differences in device-measured physical activity in a subset of children with data from 2019, 2020, to 2021

physical activity, a validated measure of physical activity [11–15], and a threefold increase in the number of patients with < 2 h of daily device-measured physical activity. Pre-school-aged children < 6 years of age did not experience a decline in device-measured physical activity. Children with elevated BMI were less active than those with non-elevated BMI during each of the study periods and there was no difference in activity between girls and boys.

These findings need to be viewed in the context of both the global COVID-19 pandemic as well as local burden of disease and local response to the pandemic. For reference, the World Health Organization declared COVID-19 a pandemic on March 1, 2020 [16] and a SIP order went into effect in Massachusetts, where a majority our study population resided, on March 24. Schools in Massachusetts were closed for in-person instruction on March 16 and remained closed through June 29. At the start of our study period, the 7-day average of new daily confirmed SARS-CoV-2 cases in Massachusetts was 0 cases per day, peaked at nearly 2500 in late April and fell to approximately 200 by the end of our study period in late June 2020 [17].

We observed a clear decline in physical activity level that corresponded with an increasing local burden of COVID-19 cases and a subsequent increase in physical activity as COVID-19 cases declined. This observation has important local and national implications about responses to surges in COVID-19 infections and future pandemics. Given that the local increase in COVID-19 cases largely coincided with the Massachusetts SIP order, it is difficult to differentiate the roles played by local burden of disease

and SIP guidelines in the reduction of device-measured physical activity we observed. It is worth noting, however, that there was a statistically significant decline in device-measured physical activity in the 2 weeks preceding the SIP order, suggesting family response to the burden of COVID-19 disease contributed to a decrease in physical activity independent of the SIP order—a response which may have been exaggerated in the families of children with cardiac disease. Additionally, we found no statistically significant reduction in device-measured physical activity in patients living in Massachusetts compared to other states in New England where COVID-19 infections were not as widespread [17], demonstrating the impact of the pandemic on physical activity across state lines and in places with variable burdens of COVID-19 disease.

In contrast to what we observed in 2020, there was no decline in device-measured physical activity from the designated baseline period to subsequent time periods in 2019, suggesting the changes we observed in 2020 are not explained by seasonal variation in physical activity level. Indeed, device-measured physical activity levels in this subset of patients were significantly lower in each time period in 2020 compared to 2019 including during the defined baseline period. Thus, behavioral modification leading to decreased physical activity likely predated the start of our study period and the decline in 2020 activity from “baseline” levels may have been even more dramatic than our analysis suggests. Interestingly, activity levels in the subset of patients for whom we abstracted 2021 device-measured physical activity level data were no different than their levels in 2019, suggesting the impact of the ongoing COVID-19 pandemic on decreasing activity levels has waned over time.

The impact of physical activity on health in children is well-established with diminished physical activity linked to a host of cardiovascular and metabolic diseases [5–9] and childhood obesity linked to stigmatization, bullying, lower self-esteem, increased frequency of anxiety and depression and increased likelihood of adulthood obesity [18–21]. Additionally, childhood physical activity has been shown to be a predictor of physical activity in adulthood [22]. Previous studies of children with underlying heart disease have reported rates of elevated BMI similar to the approximately 1 in 3 we found in the present study and thus this is an important issue for this population [21, 23–26]. Heart rhythm disturbances have been found to be risk factors for obesity possibly secondary to restricted activity secondary to increased risk (or perceived risk) with exercise [26]. Prior work in adults with CRMDs has demonstrated a beneficial impact of physical activity on secondary prevention of life-threatening arrhythmic events and reduction in ICD shocks [27–29]. These previously demonstrated associations highlight the negative impact of the reduction in device-measured physical activity observed in our study population.

Limitations of our study include its relatively small number of patients and retrospective nature. The device-measured physical activity data collected by CRMDs is binary in nature and thus does not discriminate between activity which barely meets the threshold for classification considered to be “active” and intense activity which far exceeds this threshold. Furthermore, the precise threshold and equivalent level of physical activity is not made available by the device manufacturers. These thresholds are additionally modifiable and it is possible that patients had different thresholds programmed. However, it is not our general practice to modify the activity threshold from the default setting and thus it is unlikely that this contributed to measured variations in activity between patients or in the same patient over time in a meaningful way. This analysis did not include the secondary peaks in COVID-19 infections seen in late 2020, but did include data from the same time periods in 2021.

In conclusion, we found levels of device-measured physical activity in school-aged children and adolescents with CRMDs declined in excess of 20% after the onset of the COVID-19 pandemic and institution of SIP guidelines. This decline in activity was not explained by seasonal variation in activity level and persisted for several months. Children < 6 years of age appear spared from this decline and there were no differences between girls and boys. These findings have significant implications given the demonstrated benefits of physical activity on cardiovascular and overall health in the general population, and in this population of children with underlying cardiac conditions in particular, as well as the ongoing nature of the COVID-19 pandemic and potential for future public health crises with similar effects. These data add to the evidence that the implications of the COVID-19 pandemic reach multiple areas of daily life.

Author Contributions RP: Participated study concept/design, in data collection, analysis and interpretation and authored the first draft. MC, ML: Participated in data collection and critical revision of the article and approval of the article. DM, KS, NG, SF: Provided critical revision of the article and approval of the article. JT, MA: Participated in study concept/design, provided critical revision of the article and approval of the article.

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Data Availability Data are available upon request.

Code Availability Not applicable.

Declarations

Conflict of interest The authors have no conflicts of interest relative to this article to disclose.

Ethical Approval This study was completed after obtaining a waiver of exemption from the Institutional Review Board at Boston Children’s Hospital.

Consent to Participate Not applicable.

Consent for Publication All authors provide consent for publication.

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