Western University
Scholarship@Western

Paediatrics Publications | Paediatrics Department

2-1-2021

Examining weather-related factors on physical activity levels of children from rural communities

Brenton L.G. Button
Western University

Tayyab I. Shah
Western University

Andrew F. Clark
Western University

Piotr Wilk
Western University

Jason A. Gilliland
Western University, jgillila@uwo.ca

Follow this and additional works at: https://ir.lib.uwo.ca/paedpub

Citation of this paper:
Button, Brenton L.G.; Shah, Tayyab I.; Clark, Andrew F.; Wilk, Piotr; and Gilliland, Jason A., "Examining weather-related factors on physical activity levels of children from rural communities" (2021). *Paediatrics Publications*. 1377.
https://ir.lib.uwo.ca/paedpub/1377

Canadian Journal of Public Health (2021) 112:107–114
https://doi.org/10.17269/s41997-020-00324-3

QUANTITATIVE RESEARCH

Check for updates

Examining weather-related factors on physical activity levels of children from rural communities

Brenton L. G. Button[1,2,3] • Tayyab I. Shah[1,2] • Andrew F. Clark[1,2,3] • Piotr Wilk[1,4,5,6] • Jason A. Gilliland[1,2,3,4,5,6,7]

Received: 25 September 2019 / Accepted: 13 April 2020 / Published online: 13 July 2020
© The Canadian Public Health Association 2020

Abstract

Objective The objective was to examine the influence of weather on moderate-to-vigorous physical activity (MVPA) and light physical activity (LPA) levels of children aged 8–14 years from rural communities, an understudied Canadian population.

Methods Children ($n = 90$) from four communities in rural Northwestern Ontario participated in this study between September and December 2016. Children's MVPA and LPA were measured using an Actical accelerometer and demographic data were gathered from surveys of children and their parents. Weather data were collected from the closest weather station. Cross-classified regression models were used to assess the relationship between weather and children's MVPA and LPA.

Results Boys accumulated more MVPA than girls ($b = 26.38$, $p < 0.01$), children were more active on weekdays as compared with weekends ($b = -16.23$, $p < 0.01$), children were less active on days with precipitation ($b = -22.88$, $p < 0.01$), and higher temperature led to a significant increase in MVPA ($b = 1.33$, $p < 0.01$). As children aged, they accumulated less LPA ($b = -9.36$, $p < 0.01$) and children who perceived they had higher levels of physical functioning got more LPA ($b = 25.18$, $p = 0.02$). Similar to MVPA, children had higher levels of LPA on weekdays ($b = -37.24$, $p < 0.01$) as compared to weekend days and children accumulated less LPA ($b = -50.01$, $p < 0.01$) on days with rain.

Conclusion The study findings indicate that weather influences rural children's MVPA and LPA. Future research is necessary to incorporate these findings into interventions to increase rural children's overall PA levels and improve their overall health.

Résumé

Objectif Examiner l'influence de la météo sur les niveaux d'activité physique modérée à vigoureuse (APMV) et d'activité physique légère (APL) des enfants de 8 à 14 ans vivant en milieu rural, une population canadienne sous-étudiée.

Méthode Des enfants ($n = 90$) de quatre communautés rurales du Nord-Ouest de l'Ontario ont participé à l'étude entre septembre et décembre 2016. Leurs niveaux d'APMV et d'APL ont été mesurés à l'aide d'un accéléromètre de marque Actical, et leurs données démographiques ont été obtenues en sondant les enfants et leurs parents. Les données météorologiques ont été obtenues auprès de la station météorologique la plus proche. Des modèles de régression recoupés ont servi à analyser la relation entre la météo et l'APMV et l'APL des enfants.

Résultats Les garçons ont accumulé plus d'APMV que les filles (b = 26,38 p < 0,01); les enfants étaient plus actifs les jours de semaine que les fins de semaine (b = -16,23 p < 0,01); les enfants étaient moins actifs les jours avec précipitations (b = -22,88 p < 0,01); et les températures élevées étaient associées à une augmentation significative de l'APMV (b = 1,33 p < 0,01). En

Electronic supplementary material The online version of this article (https://doi.org/10.17269/s41997-020-00324-3) contains supplementary material, which is available to authorized users.

✉ Jason A. Gilliland
jgillila@uwo.ca

1 Human Environments Analysis Laboratory, Western University, London, Ontario, Canada

2 Department of Geography, Western University, London, Ontario, Canada

3 Children's Health Research Institute, London, Ontario, Canada

4 Department of Paediatrics, Western University, London, Ontario, Canada

5 Department of Epidemiology & Biostatistics, Western University, London, Ontario, Canada

6 Lawson Health Research Institute, London, Ontario, Canada

7 School of Health Studies, Western University, London, Ontario, Canada

grandissant, les enfants accumulaient moins d'APL (b = -9,36 p < 0,01) et les enfants qui pensaient avoir des niveaux d'activité physique plus élevés accumulaient plus d'APL (b = 25,18 p = 0,02). Comme pour l'APMV, les enfants avaient des niveaux d'APL plus élevés les jours de semaine (b = -37,24 p < 0,01) que les fins de semaine, et les enfants accumulaient moins d'APL (b = -50,01 p < 0,01) les jours de pluie.

Conclusion Les constatations de l'étude montrent que la météo influence l'APMV et l'APL des enfants en milieu rural. Il faudrait pousser la recherche pour intégrer ces constatations dans des interventions pour faire augmenter les niveaux d'activité physique globaux des enfants en milieu rural et améliorer leur santé globale.

Keywords Rural · Child · Physical activity · Weather · North · Temperature

Mots-clés Milieu rural · Enfant · Activité physique · Temps (météorologie) · Nord · Température

Introduction

Research demonstrates that high levels of physical activity (PA) are associated with both short- and long-term health benefits (Poitras et al. 2016). Recently, Canada has adopted the 24-hour movement guidelines that take a more comprehensive approach to examining children's PA (Tremblay et al. 2016). This new approach recognizes the significance of both moderate-to-vigorous PA (MVPA) and light PA (LPA) each day. Yet, levels of MVPA and LPA remain disturbingly low across Canada (Colley et al. 2011).

Previous research has identified numerous demographic factors which influence children's PA levels, including ethnicity (Tremblay et al. 2006), gender (Colley et al. 2011), and age (Biddle et al. 2011). Additionally, children's PA can be influenced by parental socio-economic status (SES) (Estabrooks et al. 2003), children's perceptions of PA ability (Belanger et al. 2018), and support of PA either from parents or peers (Biddle et al. 2011). A growing body of research has shown that the environment in which children live can also influence their PA through varying accessibility to resources, such as parks and recreation centres (Oliveira et al. 2014). Although existing literature has not demonstrated differences in PA levels between children from rural and urban communities, it is known that differential access to PA supportive environmental features exists (Nykiforuk et al. 2018). Poor accessibility to recreation resources could lead rural children to participate in more outdoor PA as compared with urban children (Nykiforuk et al. 2018), necessitating an understanding of the impact of physical environment factors on PA participation across different geographic areas.

One understudied factor related to PA participation is the weather, which has differing impacts across geographic areas (Tucker and Gilliland 2007). Across Canada, there are large variations in temperature and precipitation throughout the year, but little is known about how these fluctuating weather patterns influence PA in rural areas, as most research is conducted in large urban centres (Lewis et al. 2016). This gap is problematic given disparities in children's access to supportive environmental features in rural vs. urban communities (Yousefian et al. 2009). In urban areas during poor weather, children can typically use one of many nearby recreation facilities to be active. However, in rural areas during poor weather, indoor facilities may not exist, or distance and transportation may be barriers to access (Yousefian et al. 2009). Thus, there is a critical need for researchers to better understand the determinants of PA among rural children.

This study will address two main knowledge gaps. First, there is limited literature examining the influence of weather on daily changes in children's PA. Second, this is one of the first studies to objectively examine factors that influence both MVPA and LPA in rural Canadian children. This study will address these gaps by answering the following research question: How does weather influence daily PA levels of children who live within rural communities, while accounting for child- and day-level factors?

Methods

Study design and data collection

Data were collected as part of the Spatial Temporal Environmental and Activity Monitoring (STEAM) project and additional details are described elsewhere (Mitchell et al. 2016; Loebach and Gilliland 2014). Ethics approval was granted by the University of Western Ontario's Non-Medical Research Ethics Board (NMREB: 108029) and by the two local school boards in accordance with the 1964 Helsinki declaration. The study was conducted in four elementary schools in rural Northwestern Ontario. The research team presented the details of the study to all children in grades 4–8 (ages 8–14 years). Children were provided with a package to take home to their parents, including a letter of information and parental consent form. Once the children had returned a signed parental consent form and provided their own assent, they could participate in the study.

Data for this study were collected over two 8-day periods, with the first round of data collection occurring between September 19 and October 4 of 2016 and the second round of data collection occurring between November 22 and December 7 of 2016. Child participants and parents completed a survey with questions about demographics, PA, health-related quality of life, and perceptions of their neighbourhood environments. These survey questions were based on other highly used surveys (Cerin et al. 2006; Varni et al. 1999). Children were also outfitted with a hip-worn accelerometer and a passive GPS unit that they wore for the duration of the study.

Sample

The four schools had 194 students in grades 4–8, 134 of whom agreed to participate in this study. This represents almost 70% of all eligible students. The sample was further reduced for analysis based on the following criteria: (a) child was required to meet accelerometer wear-time criteria described in the following section; (b) both child and parent completed relevant questions on the survey; and (c) child home location was identified by GPS. After applying the inclusion criteria, a final sample of 90 children with 663 valid days of data were available for further analysis.

Dependent variables: physical activity

Two dependent variables were used in this study: (a) number of minutes of MVPA per day and (b) number of minutes of LPA per day. PA was measured using an Actical® Z Accelerometer (Philips Respironics, Murrysville, PA, USA), an omni-directional device worn around the waist, sitting on either hipbone. The accelerometers measured PA in 30-s epochs, an appropriate epoch for this age group (Edwardson and Gorely 2010). The accelerometer recorded movements made by each participant in all directions and summed over a 1-min period (counts per minute, or CPM). If the device had zero counts for 60 consecutive minutes, that hour was considered invalid (Aadland et al. 2018). A valid day was considered 600 min of valid wear time (or 10 h), a threshold used in previous studies (Taylor et al. 2018). MVPA was considered to be at least 1500 CPM and LPA was considered to be at least 100 CPM (Puyau et al. 2002). A child had to have at least one valid day in each of the seasons to be included, which is appropriate as the dependent variables are included in the models at the day level.

Independent variables

Independent variables were informed by previous PA research and intended to either describe a day on which the data were collected (i.e., day-level variables) or measure characteristics of a child (i.e., child-level variables).

Day-level variables included weather factors (i.e., precipitation and temperature) and day type (weekday vs. weekend). All data for weather variables were downloaded from Canada's Environment and Natural Resources Historical Climate Data website. Two binary variables were used to measure precipitation: snow (snow vs. no snow) or rain (rain vs. no rain). These two variables were chosen as snow offers different affordances for PA compared with rain, and rain was identified as a binary variable as even small amounts of rain could prevent children from playing. Maximum temperature is a continuous variable measuring the temperature around the time that children have free time to play outside. Day type was measured for each valid day, based on whether the MVPA data were from a weekday or weekend day (Comte et al. 2013).

Child-level variables derived from the child survey included age (continuous), gender (girl vs. boy), ethnicity (Caucasian/white vs. Indigenous or visible minority), parental support (agree vs. disagree if a parent takes part in activities with you), perceptions of physical functioning (categorical), and social, neighbourhood, and safety barriers (continuous). One categorical factor assessing if the child lived directly in the settled community of Nipigon or Red Rock or in the more rural surrounding areas was created using home location from the GPS data (rural small town vs. rural). The perception of physical functioning measure was developed through four 5-point Likert scale questions from the PedsQL that pertain to how hard it is for the child to move (Varni et al. 1999) and is based on face validity. The Likert scale questions were scored from 0 to 100 in increments of 25 and averaged creating an overall score. Once an average was established, the median was used to dichotomize a child as having high or low (above or below the median) physical functioning. The social, neighbourhood, and safety barriers for PA variables were based on a composite score that was developed by computing the average of four-point Likert scale questions used to represent a child's perception of social, neighbourhood, and safety barriers to PA based on previous research (Taylor et al. 2018). The score ranges from −2 to 2 for the perception that the barriers influence PA. Child-level variables derived from the parent survey included mother's education (high school or below vs. college or above) (Estabrooks et al. 2003) and family composition (two-parent household vs. one-parent household) (McMillan et al. 2016). Only maternal education had missing data, with less than 10% of cases missing. Data were imputed using a mode fill.

Statistical analyses

Two cross-classified models were fit to examine the variation in children's daily PA levels (one model for MVPA and one model for LPA). A cross-classified model was selected because there are two independent sets of clusters in which daily PA values are nested. Daily values of PA are clustered within each child and, at the same time, they are nested within the specific dates during which the data were collected. For example, all PA data collected on a given date are more alike than data from other dates, and all PA data collected from a given child are more alike than data from other children. The cross-classified model allows us to account for this complex data structure. These models are becoming more common in children's health research (Wilk et al. 2018). To confirm that a cross-classified model is appropriate to address the research question, two preliminary models were tested: a date model and a child model for both LPA and MVPA. The results of these models suggested a significant level of clustering of daily PA values within dates ($p < 0.01$) and children ($p < 0.01$), justifying the use of the cross-classified model.

The cross-classified analysis was conducted as a stepwise process, with five models being tested. First, a null model provided an estimate of the variance in daily PA values across children and across dates (supplementary material). Second, the child-level variables were added to the null model to assess how they influence PA. Third, the day type variable (weekday vs. weekend) was entered on its own to the null model. Fourth, weather factors were added to the null model to understand how weather patterns on each date influence daily values of PA. Finally, the child-level and day-level factors were added together to assess how the two types influence daily values of PA, while accounting for each other. All data analysis was conducted in SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

Table 1 Descriptive statistics for the 663 days of data from 90 children

Dependent variables	Mean and SD
MVPA	58.6 (40.4)
LPA	262.5 (77.6)
Child-level	Count and %
Gender	
Boys	35 (38.9)
Girls	55 (61.1)
Ethnicity	
Caucasian	51 (56.7)
Indigenous and visible minority	39 (43.3)
Age, mean (SD)	10.6 (1.4)
Physical functioning, mean (SD)	88.8 (15.9)
Parents take part in activities	
Agree	50 (55.6)
Disagree	40 (44.4)
Mother's education	
High school and below	20 (22.2)
College and above	70 (77.8)
Number of parents	
One-parent household	12 (13.3)
Two-parent household	78 (86.7)
Social barrier, mean (SD)	− 0.6 (0.7)
Neighbourhood barrier, mean (SD)	− 0.8 (0.6)
Safety barrier, mean (SD)	− 1.2 (0.7)
Physical environment	
Rural small town	45 (50.0)
Rural	45 (50.0)
Day-level	Count and %
No rain or snow	16 (59.3)
Cases of rain	4 (14.8)
Cases of snow	7 (25.9)
Maximum temperature, mean (SD)	10.0 (9.5)
Daylight minutes, mean (SD)	619.1 (102.4)
Weekdays	19 (70.4)
Weekend days	8 (29.6)

Results

Table 1 presents the descriptive statistics for the continuous variables and frequency for categorical variables included in the analysis. A total of 90 children contributed 663 daily MVPA values. Children got about 58.6 min of MVPA and 262.5 min of LPA per day. The average age was 10.6 years, there were more girls than boys (61%/39%), and more people reported being Caucasian/white (57%) than being Indigenous or a visible minority (43%). The average daily maximum temperature during the study was around 10 °C, but the daily maximum temperature ranged from − 2.9 °C to 22.7 °C. Sixteen days had no precipitation, 7 days had snow, and 4 days had rain.

MVPA model

Results from the first model containing all the child-level characteristics (see Table 2) indicate that gender and maternal education were significantly associated with daily MVPA. On average, boys got 26.49 more minutes of MVPA ($b = 26.49$, $p < 0.01$) than girls, and children who had mothers with a high school education achieved 12.19 ($b = -12.19$, $p = 0.03$) more minutes of MVPA compared with children with mothers who had college education or above. Results from the second model suggest that the addition of a single day-level variable, day type, did not significantly impact MVPA. The third model, which included all weather factors, indicates that maximum temperature and rain have a significant effect on daily MVPA. On average, for each 1 °C increase in temperature across dates, children attained 1.18 more minutes of MVPA ($b = 1.18$, $p < 0.01$). Regarding precipitation, children achieved, on average, 24.38 min less of MVPA on days with rain ($b = -24.38$, $p < 0.01$). Finally, the results from

Table 2 The cross-classified model assessing the relationship between child's MVPA and child variables (model 1), day type (model 2), weather variables (model 3), and child- and day-level variables (model 4)

Variable	Category	Model 1 Est	SE	*p* value	Model 2 Est	SE	*p* value	Model 3 Est	SE	*p* value	Model 4 Est	SE	*p* value
Intercept		57.63	9.70		58.07	4.90		47.09	6.52		53.05	10.49	
Gender (*ref: girls*)	Boys	26.49	4.73	**< 0.01**							26.38	4.71	**< 0.01**
Age	Years	− 2.01	1.61	0.21							− 2.07	1.61	0.20
Ethnicity (*ref: Caucasian*)	Indigenous and visible minority	− 1.21	4.91	0.81							− 1.21	4.90	0.80
Physical functioning (*ref: low*)	High	7.02	4.99	0.16							7.03	4.97	0.16
Parents take part in activities (*ref: disagree*)	Agree	− 6.42	4.82	0.18							− 6.41	4.80	0.18
Number of parents (*ref: two*)	One	− 1.87	7.01	0.79							− 1.52	6.99	0.83
Mother's education (*ref: high school or below*)	College or above	− 12.19	5.56	**0.03**							− 12.20	5.54	**0.03**
Social barrier		− 1.39	3.41	0.68							− 1.38	3.40	0.69
Safety barrier		1.94	3.08	0.53							1.97	3.07	0.52
Neighbourhood barrier		3.70	3.59	0.30							3.75	3.58	0.29
Physical environment (*ref: rural small town*)	Rural	− 1.07	6.82	0.88							0.11	5.96	0.98
Day type (*ref: weekday*)	Weekend day				− 13.55	7.15	0.06				− 16.23	5.36	**< 0.01**
Rain days (*ref: no*)	Yes							− 24.38	8.35	**< 0.01**	− 22.88	7.73	**< 0.01**
Snow days (*ref: no*)	Yes							− 4.99	8.08	0.54	− 4.26	7.46	0.57
Maximum temperature								1.18	0.37	**< 0.01**	1.33	0.35	**< 0.01**

Terms in italics indicate reference group

Values in boldface indicate statistical significance ($p < 0.05$)

the fourth model with both child- and day-level variables identify that boys got on average 26.38 more minutes of MVPA per day as compared with girls ($b = 26.38$, $p < 0.01$), and children with mothers who had a high school education realized 12.20 more minutes of MVPA compared with children with mothers who had a college education ($b = -12.20$, $p = 0.03$). Children were less active during weekends compared with weekdays; on average, they attained 16.23 fewer minutes of MVPA ($b = -16.23$, $p < 0.01$) on weekends. Comparing rain days with days without rain or snow, children got on average 22.88 min less of MVPA ($b = -22.88$, $p < 0.01$) on days with rain. For each increase in 1 °C, there was on average a 1.33-min ($b = 1.33$, $p < 0.01$) increase in MVPA.

LPA model

The results from the first model suggest two child-level variables (Table 3), age and physical functioning, were associated with LPA; as children aged, they got 9.33 fewer minutes of LPA ($b = -9.33$, $p < 0.01$) for each 1-year increase, and children who perceived they had a higher level of physical functioning were more active ($b = 24.72$, $p = 0.02$). The second model indicates that day type significantly impacts LPA, with children accumulating 37.02 fewer minutes of LPA on weekend days ($b = -37.02$, $p < 0.01$). The results from the third model including all weather factors show that only rain had a significant effect, as children average 53.49 fewer minutes of LPA on days with rain ($b = -53.49$, $p < 0.01$). The results from the fourth model with both child- and day-level variables indicate that for each 1-year increase in age, children undertook 9.36 fewer minutes of LPA ($b = -9.36$, $p < 0.01$). Children who had higher perceptions of physical functioning were getting, on average, 25.18 more minutes of LPA ($b = 25.18$, $p = 0.02$) when compared with children who scored lower. Children who had mothers with lower educational attainment got 24.21 more minutes of LPA ($b = -24.21$, $p = 0.04$) compared with children with mothers who had higher educational attainment. Going from a weekday to a weekend day, children were getting on average 37.24 fewer minutes of LPA ($b = -37.24$, $p < 0.01$). Finally, as in the MVPA model, rain had a significant impact on LPA with children getting, on average, 50.01 fewer minutes of LPA on days with rain ($b = -50.01$, $p < 0.01$).

Discussion

The purpose of this article was to examine how weather influences daily PA levels of children who live within rural communities, while accounting for child- and day-level factors.

Table 3 The cross-classified model assessing the relationship between child's LPA and child variables (model 1), day type (model 2), weather variables (model 3), and child- and day-level variables (model 4)

Variable	Category	Model 1 Est	SE	*p* value	Model 2 Est	SE	*p* value	Model 3 Est	SE	*p* value	Model 4 Est	SE	*p* value
Intercept		261.80	19.85		261.08	7.61		255.64	13.24		272.10	21.35	
Gender (*ref: girls*)	Boys	14.78	10.02	0.14							14.89	10.20	0.14
Age	Years	− 9.33	3.43	**< 0.01**							− 9.36	3.49	**< 0.01**
Ethnicity (*ref: Caucasian*)	Indigenous and visible minority	10.42	10.42	0.32							10.59	10.60	0.32
Physical functioning (*ref: low*)	High	24.72	10.58	**0.02**							25.18	10.77	**0.02**
Parents take part in activities (*ref: disagree*)	Agree	− 4.18	10.24	0.68							− 4.31	10.42	0.68
Number of parents (*ref: two*)	One	3.22	14.82	0.83							3.55	15.06	0.81
Mother's education (*ref: high school or below*)	College or above	− 23.36	11.80	0.05							− 24.21	12.00	**0.04**
Social barrier		8.83	7.22	0.22							8.58	7.35	0.24
Safety barrier		7.52	6.54	0.25							7.79	6.56	0.24
Neighbourhood barrier		4.19	7.63	0.58							4.30	7.76	0.68
Physical environment (*ref: rural small town*)	Rural	− 4.72	13.51	0.73							3.53	12.05	0.77
Day type (*ref: weekday*)	Weekend day				− 37.02	10.95	**< 0.01**				− 37.24	9.61	**< 0.01**
Rain days (*ref: no*)	Yes							− 53.49	17.03	**< 0.01**	− 50.01	13.79	**< 0.01**
Snow days (*ref: no*)	Yes							− 4.90	16.52	0.77	− 3.45	13.04	0.79
Maximum temperature								0.24	0.76	0.76	0.49	0.61	0.42

Terms in italics indicate reference group

Values in boldface indicate statistical significance ($p < 0.05$)

This was done using cross-classified linear regressions. Previous research has indicated that season, and more specifically temperature, has an influence on PA (Lewis et al. 2016; Rich et al. 2012; Tucker and Gilliland 2007); however, little has been written about the impact of weather and seasonality on rural children's PA. This article helps fill that knowledge gap by examining the impact of weather on children's PA in a rural Northwestern Ontario setting. The findings indicate that both temperature and rain had a significant effect on children's daily MVPA, but only rain impacted LPA. It is imperative for researchers, policymakers, and recreation programmers to understand the factors that influence PA for rural populations or risk health inequities (Nykiforuk et al. 2018).

The results of this study found that boys achieved significantly more MVPA than girls, and age and perceived level of physical functioning impacted LPA, which is consistent with previous research (Biddle et al. 2011; Telford et al. 2016). Although these findings are similar to other contexts, it is important to bring this to the attention of stakeholders in rural communities. In rural communities, children are often limited in the activities that they can participate in due to greater distances and lack of accessible opportunities (Walia and Leipert 2012). Rural community leaders need to connect with girls, older children, and children who perceive they have lower levels of physical functioning and build programs for these specific groups. Specifically, community leaders need to build programs for girls to increase MVPA (e.g., girls' only hockey leagues). Additionally, more light intensity programs (e.g., free ice time to skate around) might be helpful for children with lower physical functioning or older children.

Interestingly, maternal education had a significant impact on both MVPA and LPA. Maternal education was a proxy for SES and although research is not always conclusive on SES (Biddle et al. 2011), some suggest that higher maternal education levels lead to more sedentary time and less LPA (Sherar et al. 2016). A possible explanation is in rural communities parents with higher SES might be more willing to travel farther for their child to participate in organized activities, but travelling might be having a negative impact on children's PA levels.

During weekend days, children were getting about 16 fewer minutes of MVPA and 37 fewer minutes of LPA than on weekdays. Previous research based in urban environments also indicated that children are more active on weekdays (Comte et al. 2013). A potential reason is that on school days, children normally have access to the indoor gymnasium for daily health and physical education classes, and they have two to three activity breaks when they can be physically active with schoolmates and school equipment. On the weekend, rural children typically do not have easy access to the supportive features of the school. To help combat low PA levels among rural children on weekends, local decision-makers could offer more youth-based programming with transportation supports, or incentives such as free programming to encourage children to be more physically active (Clark et al. 2018). Since children are lacking both MVPA and LPA, communities should offer diverse programs (e.g., yoga, acting classes, running clubs) and simply focus on getting children moving.

Previous studies have shown that daily PA levels are positively correlated with daily temperatures (Tucker and Gilliland 2007). Likewise, in this study, MVPA levels increased as temperature increased; each extra degree increase in temperature was related to about an 80-s increase in daily MVPA. With temperatures ranging from around − 3 °C to 23 °C in our study area, this is an average increase of about 35 min in MVPA from the coldest to warmest days. Thirty-five minutes is a substantial amount of MVPA and needs to be considered when designing programs in Northern rural communities. With winter temperatures in this area reaching average lows of − 30 °C most years, cold could have an even larger impact on MVPA; however, it is important to note that studies show that the change in PA is not linear (Remmers et al. 2017). In rural communities, the influence of temperature could be stronger because rural children do not have easy access to places to play indoors when it gets too cold outdoors. A potential way to combat weather-related drops in MVPA is to accommodate children's free play in other public facilities (e.g., libraries).

This study found that rain had a significant negative influence on children's daily PA. A study comparing Australian and Canadian children aged 9–11 years found that rainfall was negatively associated with MVPA in Australia but not in Canada (Lewis et al. 2016). In Northwestern Ontario, however, rain had a larger impact, with almost a 25-min decrease in MVPA and a 50-min decrease in LPA between days that it rained and days that it did not rain. Giving children indoor recreation opportunities has been shown to help prevent a decline in children's PA during poor weather (Harrison et al. 2011). In rural and remote areas, however, indoor recreation facilities may be too far from children's homes to represent a convenient PA opportunity. A potential solution may be to open schools after normal hours, so that children have a comfortable place to play on rainy days. Another potential solution is to use local libraries or churches as playspaces; although these spaces are not as conducive to MVPA, they can be modified for activities that are conducive to LPA (e.g., musical chairs). In contrast to rain, snow does not significantly influence total PA. A potential explanation is that snow is more fun for children than rain as it affords certain opportunities such as skiing, sliding, building snow structures, and general play in the snow.

A limitation of this study is that it did not examine spring or summer PA when temperatures are the hottest. Thus, this paper does not have a full range of weather-related variables. Nevertheless, the times were chosen as participating school principals requested that preliminary data be shared with the students before graduation and be used for the following year's school improvement plan.

Conclusion

Very little research has been conducted on children's PA in rural communities in Canada. The findings of this study indicate that weather (temperature and precipitation), gender, age, perceptions of physical functioning, maternal education, and day type had significant influences on PA. This research suggests rural children need opportunities to play inside during poor weather to support increased PA. Given its impact on PA, future research might examine interventions to overcome poor weather, or how the weather impacts other important health-related behaviours.

Acknowledgements We thank the students, parents, teachers, principals, and school research boards. We would also like to acknowledge the dozens of research assistants from the Human Environments Analysis Lab who helped with the STEAM project.

Funding information The STEAM study was jointly funded by Canadian Institutes of Health Research and the Heart and Stroke Foundation of Canada, with seed funding from the Social Sciences and Humanities Research Council of Canada. Additional support was provided by the Children's Health Research Institute and the Children's Health Foundation.

Compliance with ethical standards

Ethics approval was granted by the University of Western Ontario's Non-Medical Research Ethics Board (NMREB: 108029) and the two local school boards and done in accordance with the 1964 Helsinki declaration.

References

Aadland, E., Andersen, L. B., Anderssen, S. A., & Resaland, G. K. (2018). A comparison of 10 accelerometer non-wear time criteria and logbooks in children. *BMC Public Health*, 1–9.

Belanger, K., Barnes, J. D., Longmuir, P. E., Anderson, K. D., Bruner, B., Copeland, J. L., Gregg, M. J., Hall, N., Kolen, A. M., Lane, K. N., Law, B., Macdonald, D. J., Martin, L. J., Saunders, T. J., Sheehan, D., Stone, M., Woodruff, S. J., & Tremblay, M. S. (2018). The relationship between physical literacy scores and adherence to Canadian physical activity and sedentary behaviour guidelines. *BMC Public Health, 18*(Suppl 2).

Biddle, S. J. H., Atkin, A. J., Cavill, N., & Foster, C. (2011). Correlates of physical activity in youth: a review of quantitative systematic reviews. *Int Rev Sport Exerc Psychol, 4*(1), 25–49. https://doi.org/10.1080/1750984X.2010.548528.

Cerin, E., Saelens, B. E., Sallis, J. F., & Frank, L. D. (2006). Neighborhood environment walkability scale: validity and development of a short form. *Med Sci Sports Exerc, 38*(9), 1682–1691. https://doi.org/10.1249/01.mss.0000227639.83607.4d.

Clark, A. F., Wilk, P., Mitchell, C. A., Smith, C., Archer, J., & Gilliland, J. A. (2018). Examining how neighborhood socioeconomic status, geographic accessibility, and informational accessibility influence the uptake of a free population-level physical activity intervention for children. *Am J Health Promot, 32*(2), 315–324. https://doi.org/10.1177/0890117117718433.

Colley, R. C., Garriguet, D., Janssen, I., Craig, C. L., Clarke, J., & Tremblay, M. S. (2011). Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep, 22*(1), 15–23. https://doi.org/10.1016/j.yspm.2011.03.006.

Comte, M., Hobin, E., Majumdar, S. R., Plotnikoff, R. C., Ball, G. D. C., & McGavock, J. (2013). Patterns of weekday and weekend physical activity in youth in 2 Canadian provinces. *Appl Physiol Nutr Metab, 38*(2), 115–119. https://doi.org/10.1139/apnm-2012-0100.

Edwardson, C. L., & Gorely, T. (2010). Epoch length and its effect on physical activity intensity. *Med Sci Sports Exerc*, 928–934. https://doi.org/10.1249/MSS.0b013e3181c301f5.

Estabrooks, P., Lee, R., & Gyurcsik, N. (2003). Resources for physical activity participation: does availability and accessibility differ by neighborhood socioeconomic status? *Ann Behav Med, 25*(2), 80–91.

Harrison, F., Jones, A. P., Bentham, G., Van Sluijs, E. M. F., Cassidy, A., & Griffin, S. J. (2011). The impact of rainfall and school break time policies on physical activity in 9-10 year old British children: a repeated measures study. *Int J Behav Nutr Phys Act, 8*(1), 47. https://doi.org/10.1186/1479-5868-8-47.

Lewis, L. K., Maher, C., Belanger, K., Tremblay, M., Chaput, JP., & Olds, T. (2016). At the mercy of the gods: associations between weather, physical activity, and sedentary time in children. *Pediatr Exerc Sci*, 152–163.

Loebach, J. E., & Gilliland, J. A. (2014). Free range kids? Using GPS-derived activity spaces to examine children's neighborhood activity and mobility. *Environ Behav, 48*(3), 421–453.

McMillan, R., Mcisaac, M., & Janssen, I. (2016). Family structure as a correlate of organized sport participation among youth. *PLoS One, 11*(2), 1–12. https://doi.org/10.1371/journal.pone.0147403.

Mitchell, C, Clark, A. F., & Gilliland J. A. (2016). Built environment influences of children's physical activity: Examining differences by neighbourhood size and sex. *Int J Environ Res Public Health, 13*(1), 130.

Nykiforuk, C. I. J., Atkey, K., Brown, S., Caldwell, W., Galloway, T., Gilliland, J., Kongats, K., McGavock, J., & Raine, K. D. (2018). Promotion of physical activity in rural, remote and northern settings: a Canadian call to action. *Health Promot Chronic Dis Prev Can, 38*(11), 419–435. https://doi.org/10.24095/hpcdp.38.11.03.

Oliveira, A. F., Moreira, C., Abreu, S., Mota, J., & Santos, R. (2014). Environmental determinants of physical activity in children: a systematic review. *Arch Exec Health Dis, 4*(2), 254–261.

Poitras, V. J., Gray, C. E., Borghese, M., Carson, V., Chaput, J.-P., Janssen, I., Katzmarzyk, P. T., Pate, R. R., Gorber, S. C., Kho, M. E., Sampson, M., & Tremblay, M. S. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab, 41*.

Puyau, M. R., Adolph, A. L., Vohra, F. A., & Butte, N. F. (2002). Validation and Calibration of Physical Activity Monitors in Children. *Obesity, 10*(3)

Remmers, T., Thijs, C., Timperio, A., Salmon, J., Veitch, J., Kremers, S., & Ridgers, N. (2017). Daily weather and children's physical activity patterns. *Med Sci Sports Exerc, 25*, 922–929.

Rich, C., Griffiths, L. J., & Dezateux, C. (2012). Seasonal variation in accelerometer-determined sedentary behaviour and physical activity in children: a review. *Int J Behav Nutr Phys Act, 9*(1), 49. https://doi.org/10.1186/1479-5868-9-49.

Sherar, L. B., Griffin, T. P., Ekelund, U., Cooper, A. R., Esliger, D. W., van Sluijs, E. M. F., Andersen, L. B., Cardon, G., Davey, R., Froberg, K., Hallal, P. C., Janz, K. F., Kordas, K., Kriemler, S., Pate, R. R., Puder, J. J., Sardinha, L. B., Timperio, A. F., & Page, A. S. (2016). Association between maternal education and objectively measured physical activity and sedentary time in adolescents. *J Epidemiol Community Health, 70*(6), 541–548. https://doi.org/10.1136/jech-2015-205763.

Taylor, L., Clark, A., Wilk, P., Button, B., & Gilliland, J. (2018). Exploring the effect of perceptions on children's physical activity in varying geographic contexts: using a structural equation modelling approach to examine a cross-sectional dataset. *Children, 5*(12), 159. https://doi.org/10.3390/children5120159.

Telford, R. M., Telford, R. D., Olive, L. S., Cochrane, T., & Davey, R. (2016). Why are girls less physically active than boys? Findings from the LOOK longitudinal study. *PLoS One, 11*(3), 1–11. https://doi.org/10.1371/journal.pone.0150041.

Tremblay, M., Bryan, S., Perez, C., Ardern, C., & Katzmarzyk, P. (2006). Physical activity and immigrant status: evidence from the Canadian community health survey. *Can J Public Health, 97*(4), 277–282.

Tremblay, M. S., Carson, V., Chaput, J. P., Connor Gorber, S., Dinh, T., Duggan, M., ... Zehr, L. (2016). Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. *Appl Physiol Nutr Metab, 41*(6), S311–S327. https://doi.org/10.1139/apnm-2016-0151.

Tucker, P., & Gilliland, J. (2007). The effect of season and weather on physical activity: a systematic review. *Public Health, 121*(12), 909–922. https://doi.org/10.1016/j.puhe.2007.04.009.

Varni, J., Seid, M., & Rode, C. (1999). The PedsQL: measurement model for the pediatric quality of life inventory. *Med Care, 37*(2).

Walia, S., & Leipert, B. (2012). Perceived facilitators and barriers to physical activity for rural youth: an exploratory study using photovoice. *Rural Remote Health, 12*, 1842.

Wilk, P., Clark, A. F., Maltby, A., Smith, C., Tucker, P., & Gilliland, J. A. (2018). Examining individual, interpersonal, and environmental influences on children's physical activity levels. *SSM Popul Health, 4*(June 2017), 76–85. https://doi.org/10.1016/j.ssmph.2017.11.004.

Yousefian, A., Ziller, E., Swartz, J., & Hartley, D. (2009). Active living for rural youth: addressing physical inactivity in rural communities. *J Public Health Manag Pract, 15*(3), 223–231. https://doi.org/10.1097/PHH.0b013e3181a11822.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.