A methodology to leverage cross-sectional accelerometry to capture weather's influence in active living research

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ABSTRACT

OBJECTIVES: While active living interventions focus on modifying urban design and built environment, weather variation, a phenomenon that perennially interacts with these environmental factors, is consistently underexplored. This study's objective is to develop a methodology to link weather data with existing cross-sectional accelerometry data in capturing weather variation.

METHODS: Saskatoon's neighbourhoods were classified into grid-pattern, fractured grid-pattern and curvilinear neighbourhoods . Thereafter, 137 Actical accelerometers were used to derive moderate to vigorous physical activity (MVPA) and sedentary behaviour (SB) data from 455 children in 25 sequential one-week cycles between April and June, 2010. This sequential deployment was necessary to overcome the difference in the ratio between the sample size and the number of accelerometers. A data linkage methodology was developed, where each accelerometry cycle was matched with localized (Saskatoon-specific) weather patterns derived from Environment Canada. Statistical analyses were conducted to depict the influence of urban design on MVPA and SB after factoring in localized weather patterns.

RESULTS: Integration of cross-sectional accelerometry with localized weather patterns allowed the capture of weather variation during a single seasonal transition. Overall, during the transition from spring to summer in Saskatoon, MVPA increased and SB decreased during warmer days. After factoring in localized weather, a recurring observation was that children residing in fractured grid-pattern neighbourhoods accumulated significantly lower MVPA and higher SB.

CONCLUSION: The proposed methodology could be utilized to link globally available cross-sectional accelerometry data with place-specific weather data to understand how built and social environmental factors interact with varying weather patterns in influencing active living.

KEY WORDS: Weather; physical activity; sedentary lifestyle

La traduction du résumé se trouve à la fin de l'article.

Can J Public Health 2016;107(1):e30–e36
doi: 10.17269/CJPH.107.5242

Active living research is gaining global recognition as it has the potential to address health inequities by informing upstream policy interventions for creating active urban communities.[1] While active living research focuses on modifying urban design and built environment, weather variation, a phenomenon that perennially interacts with human modified spaces, has been consistently underexplored. The significance of weather variation's influence on physical activity (PA) is especially important in temperate and continental climatic zones (Köppen-Geiger climate classification) due to a wide variation in seasonal weather in these regions.[2]

In Canada, the majority of the population experiences a substantial variation in seasonal temperatures and weather conditions.[2–4] Within Canada, prairie provinces like Saskatchewan, where this study was conducted, are known for particularly extreme variations in seasonal weather.[3,4] Moreover, there is evidence to indicate that the relationship between seasonality and PA is stronger in Saskatchewan.[5] Earth's weather conditions are interrelated and dynamic in nature, with the interactions between many weather variables creating place-specific weather patterns.[6] However, when the relationship between weather and PA has been investigated, thus far the focus of research has only been on isolated weather variables such as temperature and precipitation.[7–12]

Nevertheless, active living research has advanced considerably in terms of utilizing accelerometers to objectively measure PA. Accelerometers are devices that are worn around the waist by participants and they measure frequency, intensity and duration of PA.[13] With advances in methodological expertise in accelerometry encompassing a wide range of categories, including reliability and validity of accelerometers, development of calibration protocols, and creation of data reduction methods,[13–16] these devices have become the gold standard for objective measurement of PA.

More importantly, to date most active living research has been cross-sectional, resulting in large sets of accelerometry data from cohorts across the world.[17] These data have been under-utilized as

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Acknowledgements: The authors acknowledge the Smart Cities, Healthy Kids research team and staff. Smart Cities, Healthy Kids study is funded by the Canadian Institutes of Health Research, Heart and Stroke Foundation of Canada, and R&D: Health Research Foundation.

Conflict of Interest: None to declare.

they have not been linked to readily available weather data to factor in weather variation in analyses exploring urban design and built environment's influence on PA. We hypothesize that in active living research, not only could weather variation be captured, but localized (place-specific) weather patterns could also be established within a short time period in a calendar year.

Based on this hypothesis, this study aimed to develop a methodology to link existing cross-sectional accelerometry data with place-specific weather data in capturing weather variation during a single seasonal transition (spring to summer) in the Canadian prairie city of Saskatoon. During this short period of time, after factoring in localized weather patterns, we also aimed to depict the influence of urban design on active living. In depicting this influence, we conceptualized weather as a complex entity consisting of interrelated elements that can be combined to categorize localized weather patterns.

METHODS

This study is part of an active living research initiative in Saskatoon called Smart Cities, Healthy Kids. The study protocol was approved by the University of Saskatchewan's Research Ethics Board.

Urban design of Saskatoon

Saskatoon's metropolitan area population of 260,600 is spread across 65 well-defined neighbourhoods.[18] The city plays a major role in urban planning, including the geographic allocation of commercial, residential and institutional establishments. The neighbourhoods designed prior to 1930 surround the city centre and follow a traditional grid-patterned street design, typified by higher density, mixed-use neighbourhoods connected by straight, intersecting streets and back alleys.

The semi-suburban neighbourhoods built between 1931 and 1966 follow a fractured grid-pattern. Fractured grid-pattern neighbourhoods are predominantly residential, have lower density and become progressively car-oriented as the distance from the urban centre increases. Finally, the suburban neighbourhoods built after 1967 follow curvilinear street patterns, characterized by low-density, almost exclusively residential and highly car-oriented configurations. Working with the City of Saskatoon's Neighbourhood Planning Department, our research team has confirmed that the three neighbourhood designs described here are consistent with the different planning principles and practices prevalent in Saskatoon during different time periods since the city's inception.[19]

Recruitment

All schools in Saskatoon were invited to participate in the study. Recruitment was conducted through 30 elementary schools that accepted to participate. The total sample was representative of all types of neighbourhoods. We identified four classrooms at each elementary school (grades 5–8) and each school was provided with letters of consent to be given to each potential participant to deliver to their primary caregiver. Caregivers had to return signed forms to their child's homeroom teacher. It was made explicit in the consent form that caregivers or children would be able to opt out of participating at any time, until the data were pooled. Of the 1,610 children aged 10–14 years who agreed to participate in the Smart Cities Healthy Kids initiative, 455 children agreed to participate in accelerometry. This study exclusively focuses on children who participated in accelerometry.

Table 1. Classification of accelerometer cut-points delineating activity intensities

Intensity	Active energy expenditure (kcal kg^{-1} min^{-1})	Activity examples	Accelerometer count range (counts per min)
MVPA	≥0.04	Walking at speeds of ≥3.2 km/h, running	≥1500
SB	<0.01	Sitting, screen time	<100

MVPA = moderate to vigorous physical activity; SB = sedentary behaviour; kcal = kilocalorie; kg = kilogram; min = minute; km/h = kilometre per hour.
Note: Adapted from "Physical activity of Canadian children and youth: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey," by R. C. Colley et al., 2011, *Health Reports* 22(1), 15–23.

Accelerometry

A total of 137 Actical accelerometers (Mini Mitter Co., Inc., Bend, OR, USA) were deployed through schools from April to June in 2010 to capture activity data of 455 children residing in Saskatoon. Children were visited at their respective schools and were asked to wear the devices on their right hip using an elastic belt, every day for 7 consecutive days. They were advised to remove the accelerometers during night-time sleep and during any water-based activities. Children were asked to return the accelerometers at the end of the 7-day cycle. The devices began measuring data at 00:00 on the day following device deployment (i.e., almost a full day after the device was deployed) to minimize the potential for subject reactivity within the first day of wearing the accelerometer.

Accelerometers measure movement in time-stamped activity counts which are sequentially aggregated to a predetermined period of time to delineate intensities of activity that occur throughout the day. The raw data thus obtained were analyzed using KineSoft version 3.3.63 (KineSoft, Loughborough, UK), a custom software which reaggregates activity counts to one minute to produce a series of activity intensities that represent the complete range of daily waking activity: moderate to vigorous physical activity (MVPA), light physical activity (LPA) and sedentary behaviour (SB). Activity intensities were derived using cut-points (SB: <100 counts/min; LPA: 100 to <1500 counts/min; MVPA: ≥1500 counts/min) based on evolving evidence (Table 1).[20]

The accelerometers and cut-points used in this study are the same as those used in the 2007–2009 Canadian Health Measures Survey (CHMS),[20] whose accelerometry results depicted activity patterns in a nationally representative sample of children in Canada. Furthermore, using the accelerometer sample of the 2007–2009 CHMS, operational definitions and data reduction techniques were developed by Colley et al.[13] These definitions and techniques were adopted to generate valid data for our study. Generation of valid data is essential to avoid including days when the participants did not wear the device, or wore the device for a period which is deemed insufficient to interpret levels of activity.[13,20]

A valid day was defined as a day of accelerometry with 10 or more hours of wear-time.[16] Daily wear-time was estimated by subtracting non-wear-time from 24 h of that particular day. It was determined that non-wear-time would be a period of at least 60 consecutive minutes of zero counts, including up to 2 min of counts between 0

Table 2. Descriptive characteristics of the study sample depicted across urban design

Variables	Total	Grid	Fractured grid	Curvilinear
Sampled schools	30	6	10	14
Total sample	331	95	100	136
Boys	166	45	53	68
Girls	165	50	47	68
Age (years)				
10	70	16	25	29
11	91	32	22	37
12	85	27	26	32
13	64	13	23	28
14	21	7	4	10
Mean age (SD; Min, Max)	11.6 (1.1; 10, 14)	11.6 (1.1; 10, 14)	11.5 (1.2; 10, 14)	11.63 (1.2; 10, 14)
Mean body mass index (SD; Min, Max)	19.9 (4; 13.4, 35.9)	19.8 (4.2; 14, 35.9)	20.3 (4.2; 13.4, 34.3)	19.7 (3.7; 14.2, 33.8)
Mean accelerometer wear-time/day (SD; Min, Max)	796.3 (51.1; 653.3, 930.2)	794 (53.1; 680.8, 930.2)	797 (53.3; 653.3, 915)	797.3 (48.1; 684.5, 910.6)
Mean MVPA/day (SD; Min, Max)	71.2 (31.8; 8, 234.5)	72.8 (33.7; 8, 178.1)	67.3 (32.9; 13.3, 234.5)	73.1 (29.4; 16.6, 182)
Mean SB/day (SD; Min, Max)	540.2 (64.8; 317.4, 691.3)	537.8 (68.9; 317.4, 682.6)	546 (70.5; 344, 691.3)	537.3 (57; 379.7, 663.4)

SD = standard deviation; Min = minimum; Max = maximum; MVPA = moderate to vigorous physical activity; SB = sedentary behaviour; Accelerometer wear-time, MVPA and SB values are expressed in minutes.

and 100.[13] The final sample consisted of data from children with at least four valid days including at least one valid weekend day, i.e., the valid sample. Table 2 compares the distribution of the valid sample (331 participants) across the urban design of Saskatoon.

However, even within valid data, there is a chance for systematic variation in daily wear-time, both within (on different days of accelerometer use) and between participants. The systemic variation occurs because even though participants are asked to wear accelerometers from the time they wake up in the morning until the time they go to bed at night, every participant wears or removes the accelerometer at her/his discretion, thus potentially introducing a random or non-random measurement bias to activity measurement. We have previously developed a methodology to minimize this measurement bias by standardization of valid data.[21]

The previously developed standardization methodology used the same accelerometer data that were used in this study.[21] The standardization methodology compared pre- and post-standardized activity intensities (i.e.,MVPA and SB) to understand discrepancies owing to wear-time variation. The analyses revealed systematic wear-time variation, both between and within participants within the valid data. The conclusions determined that standardization of accelerometer data is effective not only in minimizing measurement bias due to systematic wear-time variation, but also in providing a uniform platform to compare results within and between populations and studies. The same standardization methodology has been replicated in this study to standardize valid data.

Integration of localized weather with cross-sectional accelerometry

Accelerometer data were obtained in 25 sequential one-week cycles between April 28 and June 11, 2010 (45-day transition period from spring to summer). This sequential deployment was necessary to overcome the difference in the ratio between the sample size and the number of accelerometers (137/455). Each one-week cycle of accelerometry was conducted on a different group of children within the total sample. To match the accelerometry period, detailed Saskatoon-specific weather data for the days between April 28 and June 11, 2010 were obtained from Environment Canada.[22] On the basis of previous evidence,[7–12,23] extensive exploration of the weather data was conducted to identify daily values of key weather variables corresponding to the accelerometry period: maximum temperature, precipitation, speed of maximum wind gust and hours of illumination.

Descriptive analyses were conducted to understand the distribution (i.e.,mean, median, standard deviation [SD]) of daily values of the selected weather variables during the 45 days of accelerometry in question (Table 3). After confirming the normal distribution of daily values of weather variables, these were aggregated to their corresponding one-week cycle of accelerometry to calculate their mean values/week. A decision rule was then applied, where a cut-point of 1 SD of the distribution of daily weather values during the 45 days of accelerometry was chosen to categorize weekly values of weather variables as follows: maximum temperature: ≥1 SD = Warm (>22.05°C); <1 SD = Cold (<9.55°C); precipitation: ≥1 SD = Wet (>12.26 mm); <1 SD = Dry (<−3.66 mm); speed of maximum wind gust: ≥1 SD = Windy (58.71 km/h); <1 SD = Calm (34.17 km/h).

Thereafter, each week of accelerometry was assigned three categories (Warm/Cold; Wet/Dry; Windy/Calm) based on mean weekly weather values. Finally, the three categories assigned to each week of accelerometry were combined to derive one of the following four localized weather patterns for each week of accelerometry (weekly weather): Warm-Wet-Calm, Cold-Dry-Calm, Cold-Dry-Windy and Cold-Wet-Calm. Although, mathematically, the possible combination of weather patterns is higher than four, it is important to highlight that the classification of localized weather patterns is based on actual weather recorded during the period of accelerometry. As the range (2.26) and SD (0.69) of hours of illumination during the 45 days of accelerometry was negligible, mean (weekly) hours of illumination was excluded from this classification.

Statistical analyses

Only wear-time controlled standardized valid accelerometer data (i.e., valid sample: 331 children) were used in the analyses. The outcome variables for this study were MVPA and SB. First, for each cohort of accelerometry (25 in total), MVPA and SB were

Table 3. Distribution of selected weather variables over the period of accelerometry implementation (April 28 to June 11, 2010), Smart Cities, Healthy Kids study, Saskatoon, Saskatchewan

	Maximum temperature (°C)	Precipitation (mm)	Speed of maximum wind gust (km/h)	Hours of illumination
Definition	The highest temperature in °C observed at a location for a specified time interval	Any and all forms of water, liquid or solid that falls from clouds and reaches the ground	The speed in km/h of the maximum wind gust during the day	Duration of daylight hours from sunrise to sunset, plus the duration of morning and evening twilight
Mean	15.80	4.30	46.44	17.32
Standard deviation	6.25	7.96	12.27	0.69
Range	23.00	38.60	45.00	2.26
Minimum	6.00	0.00	31.00	16.03
Maximum	29.00	38.60	76.00	18.29
Cut-point to simulate localized weather	22.05	12.26	58.71	N/A

°C = degrees Celsius; mm = millimetre; km/h = kilometre per hour; Note: The cut-points shown here are 1 SD of the distribution of daily weather values during the 45 days of accelerometry; SD = standard deviation.

Table 4. ANOVA testing group differences in MVPA and SB during different types of localized weather patterns

	Cold-Dry-Calm	Cold-Dry-Windy	Cold-Wet-Calm	Warm-Wet-Calm
Group differences in MVPA during different types of localized weather				
Cold-Dry-Calm	0.00	10.63***	−0.77	−6.4
Cold-Dry-Windy	−10.63	0.00	−11.4	−17.11
Cold-Wet-Calm	0.77	11.40***	0.00	−5.7
Warm-Wet-Calm	6.48***	17.11***	5.70***	0.00
Group differences in SB during different types of localized weather				
Cold-Dry-Calm	0.00	−9.96	2.69	11.06***
Cold-Dry-Windy	9.96**	0.00	12.66***	21.03***
Cold-Wet-Calm	−2.69	−12.66	0.00	8.36**
Warm-Wet-Calm	−11.06	−21.03	−8.36	0.00

Note: Each value presented in the tables is a result of subtraction of group MVPA and SB between 2 types of localized weather patterns; ** $p < 0.01$; *** $p < 0.001$; ANOVA = analysis of variance; MVPA = moderate to vigorous physical activity; SB = sedentary behaviour.

aggregated to their corresponding one-week cycle of accelerometry to calculate mean cohort MVPA and SB. Thereafter, analysis of variance (ANOVA) was conducted to assess group differences in mean MVPA and SB between children who experienced the four types of localized weather patterns (Warm-Wet-Calm, Cold-Dry-Calm, Cold-Dry-Windy and Cold-Wet-Calm). Finally, ANOVA was conducted to assess group differences in mean MVPA and SB between children residing in neighbourhood types of Saskatoon after factoring in localized weather patterns.

RESULTS

Between the four types of localized weather patterns, the group differences in mean MVPA and SB point towards a pattern: Warm-Wet-Calm weather was associated with significantly lower SB and higher MVPA, whereas Cold-Dry-Windy weather was associated with significantly higher SB and lower MVPA. For instance, in a week, on average, children who experienced Warm-Wet-Calm weather accumulated 6.48, 17.11 and 5.70 more minutes of MVPA/day in comparison with children who experienced Cold-Dry-Calm, Cold-Dry-Windy and Cold-Wet-Calm weather (Table 4). Similarly, children who experienced Warm-Wet-Calm-weather accumulated fewer minutes of SB/day in comparison with the children who experienced all other weather patterns. Among the cold weather patterns, children who experienced Cold-Dry-Calm and Cold-Wet-Calm weather accumulated significantly more MVPA and less SB in comparison with children who accumulated Cold-Dry-Windy weather pattern.

Between the children residing in different types of neighbourhoods, after factoring in localized weather patterns, a recurring observation was that in all weather patterns, children residing in fractured grid-pattern neighbourhoods accumulated significantly lower MVPA (Table 5) and higher SB (Table 6) in comparison with children residing in grid-pattern and curvilinear pattern neighbourhoods.

For example, in Cold-Dry-Windy weather, children in fractured grid-pattern neighbourhoods accumulated 3.07 and 7.49 fewer minutes of MVPA/day in comparison with children in grid and curvilinear neighbourhoods. Similarly, in Warm-Wet-Calm weather, children in fractured grid-pattern neighbourhoods accumulated 13.70 and 20.01 more minutes of SB/day in comparison with children in grid and curvilinear neighbourhoods.

DISCUSSION

The purpose of this study was to develop a methodology to link cross-sectional accelerometry data with place-specific weather data in capturing weather variation during a single seasonal transition in Saskatoon. This linkage enabled the depiction of the influence of urban design on MVPA and SB after factoring in localized weather patterns.

The first step in the analysis was to appreciate the deployment process of accelerometers in the parent study of Smart Cities,

Table 5. ANOVA testing group differences in MVPA between different types of neighbourhoods stratified by localized weather patterns

MVPA accumulation – Warm-Wet-Calm

	Grid	Fractured	Curvilinear
Grid	0.00	3.67	−5.46
Fractured	−3.67	0.00	−9.13***
Curvilinear	5.46	9.13***	0.00

MVPA accumulation – Cold-Dry-Windy

	Grid	Fractured	Curvilinear
Grid	0.00	0.00	N/A
Fractured	0.00	0.00	N/A
Curvilinear	N/A	N/A	0.00

MVPA accumulation – Cold-Dry-Calm

	Grid	Fractured	Curvilinear
Grid	0.00	3.07	−4.41
Fractured	−3.07	0.00	−7.49***
Curvilinear	4.41	7.49***	0.00

MVPA accumulation – Cold-Wet-Calm

	Grid	Fractured	Curvilinear
Grid	0.00	6.31***	3.78
Fractured	−6.31***	0.00	−2.52
Curvilinear	−3.78	2.52	0.00

Note: Each value presented in the tables is a result of subtraction of group MVPA between 2 types of urban design (values in rows subtracted from values in columns); ****p* < 0.001; ***p* < 0.01; ANOVA = analysis of variance; MVPA = moderate to vigorous physical activity.

Table 6. ANOVA testing group differences in SB between different types of neighbourhoods stratified by localized weather patterns

SB accumulation – Warm-Wet-Calm

	Grid	Fractured	Curvilinear
Grid	0.00	−13.7*	6.31
Fractured	13.7*	0.00	20.01***
Curvilinear	6.31	−20.01***	0.00

SB accumulation – Cold-Dry-Windy

	Grid	Fractured	Curvilinear
Grid	0.00	0.00	N/A
Fractured	0.00	0.00	N/A
Curvilinear	N/A	N/A	0.00

SB accumulation – Cold-Dry-Calm

	Grid	Fractured	Curvilinear
Grid	0.00	−7.24	4.29
Fractured	7.24	0.00	11.53***
Curvilinear	−4.29	−11.53***	0.00

SB accumulation – Cold-Wet-Calm

	Grid	Fractured	Curvilinear
Grid	0.00	−9.19***	−4.09
Fractured	9.19***	0.00	5.10
Curvilinear	4.09	−5.10	0.00

Note: Each value presented in the tables is a result of subtraction of group SB between 2 types of urban design (values in rows subtracted from values in columns); ****p* < 0.001; ***p* < 0.01; ANOVA = analysis of variance; SB = sedentary behaviour.

Healthy Kids. Due to the difference in the ratio between the accelerometers and the sample size, deployment of accelerometers took place over a period of 45 days (April 28 to June 11, 2010) to cross-sectionally capture PA and SB data. Employing a smaller number of accelerometers to capture data from a much larger study sample resulted in redeploying accelerometers in 25 sequential one-week cycles. Each one-week cycle of accelerometry was conducted on a different group of children within the total sample.

This deployment process enabled us to link accelerometry with weather data to capture weather variation within a short period of time with a cross-sectional design. To our knowledge, this method of leveraging cross-sectional accelerometry has not been employed previously.

The next step was to derive localized weather patterns and explore the influence of weather variation on MVPA and SB. The final step was to show that weather variation could influence active living even during a single seasonal transition. Initial results suggested Warm-Wet-Calm weather was associated with both higher MVPA and lower SB. On the other hand, Cold-Dry-Windy weather was consistently associated with lower MVPA and higher SB. It is apparent that exposure to higher daily temperatures played a role in higher MVPA and lower SB accumulation. Although previous studies have shown that higher temperatures in temperate climatic zones are associated with higher PA,[7–12] similar findings have not been established for SB.

Localized weather patterns portray a more nuanced picture. For instance, in both Warm-Wet-Calm and Cold-Dry-Windy weather patterns, irrespective of the amount of precipitation (wet or dry), temperature and speed of maximum wind gust influenced MVPA and SB accumulation. Similarly, reiterating the key role played by speed of maximum wind gust, among the cold weather patterns, children who experienced Cold-Dry-Calm and Cold-Wet-Calm weather accumulated significantly more MVPA and less SB in comparison with children who experienced Cold-Dry-Windy weather pattern. Theses gradations underline the need to account for the interrelated dynamics of specific characteristics such as temperature, wind speed and precipitation.

More importantly, the real focus should be on how modifiable factors such as urban design and built environment moderate the influence of variation in weather on MVPA and SB. After factoring in localized weather patterns, when MVPA and SB accumulation was compared between children living in different types of neighbourhoods, a clear pattern emerged. Children residing in grid-pattern and curvilinear neighbourhoods consistently accumulated higher MVPA and lower SB than children living in fractured-grid pattern neighbourhoods.

The grid-pattern neighbourhoods surrounding the city centre, by virtue of their mixed land-use (combination of commercial, residential, institutional establishments), possess greater density and diversity of destinations, are less car-oriented and are more pedestrian friendly.[19] While mixed land-use is known to be a strong predictor of PA among adolescents,[24] curvilinear neighbourhoods, which do not have mixed-land use and are distinct from grid-pattern neighbourhoods in being highly car-oriented, were also associated with higher MVPA and lower SB. Curvilinear neighbourhoods also represent the higher socio-economic areas of Saskatoon and existing evidence does indicate that higher socio-economic status is associated with higher PA and lower SB in children.[25,26] Nevertheless, these findings suggest that two contrasting types of urban design can have a positive influence on active living in children (i.e.,higher MVPA and lower SB) after factoring in localized weather patterns.

Strengths and limitations

The primary strength of the study is the development of a methodology to link cross-sectional accelerometry with weather data. Moreover, this study explores the conceptualization of weather as a complex entity consisting of interrelated dynamics between individual weather variables. The overall approach of the study could be replicated to link existing cross-sectional accelerometry data sets with place-specific weather data to factor in weather variation in active living research. The proposed methodology takes advantage of sequential cross-sectional accelerometry in a large study sample due to logistical and resource constraints. However, other existing cross-sectional accelerometry data could have been collected through multiple variations of the sequential deployment described in our study. Thus, future linking of cross-sectional accelerometry with weather data should adapt the proposed methodology to account for variations in deployment.

The decision rules applied to derive localized weather patterns were based on cut-points that allowed the quantitative derivation of localized weather patterns. The aim of the cut-points was to enable the capture of relative differences between the derived weather patterns and not the absolute depiction or classification of weather. This concept needs to be taken into consideration while interpreting the results. Finally, the four derived localized weather patterns were the result of actual weather that was observed during the 45-day period of accelerometry and does not include all other potential weather patterns. Nevertheless, this reiterates the strength of the methodology in capturing weather variation even during a short period of time (i.e.,the transition from spring to summer).

CONCLUSION

Weather variation could be captured in active living research within a short time period in a calendar year by linking cross-sectional accelerometry with place-specific localized weather patterns. It is necessary to derive localized weather patterns to take into account the interrelated dynamics of individual weather variables. In advancing active living research, it is essential to factor in weather variation, especially in a country like Canada where a wide variation in weather patterns is experienced across the year. This study proposes a methodology that could be replicated to link existing cross-sectional accelerometry data with place-specific weather data to understand how human-modifiable environmental factors can influence active living in all weather conditions.

REFERENCES

1. Arline-Bradley SL. Uneven playing field – Effective strategies to address health inequity through active living research: A commentary to accompany the active living research supplement to annals of behavioral medicine. *Ann Behav Med* 2013;45(1):9–10. PMID: 23334769. doi: 10.1007/s12160-012-9447-5.
2. Peel MC, Finlayson BL, McMahon TA. Updated world map of the Köppen-Geiger climate classification. *Hydrol Earth Syst Sci* 2007;11:1633–44. doi: 10.5194/hess-11-1633-2007.
3. Frittis HC, Lough JM. An estimate of average annual temperature variations for North America, 1602 to 1961. *Clim Change* 1985;7:203–24. doi: 10.1007/BF00140506.
4. Zhang X, Vincent LA, Hogg WD, Niitsoo A. Temperature and precipitation trends in Canada during the 20th century. *Atmos Ocean* 2000;38(3):395–429. doi: 10.1080/07055900.2000.9649654.
5. Merchant AT, Dehghan M, Akhtar-Danesh N. Seasonal variation in leisure-time physical activity among Canadians. *Can J Public Health* 2007;98(3):203–8. doi: 10.17269/cjph.98.823.
6. Sheridan SC. The redevelopment of a weather-type classification scheme for North America. *Int J Climatol* 2002;22:51–68. PMID: 25855820. doi: 10.1002/joc.709.
7. Kolle E, Steene-Johannessen J, Andersen LB, Anderssen SA. Seasonal variation in objectively assessed physical activity among children and adolescents in Norway: A crosssectional study. *Int J Behav Nutr Phys Act* 2009;6:36. PMID: 19563650. doi: 10.1186/1479-5868-6-36.
8. Kristensen PL, Korsholm L, Møller NC, Wedderkopp N, Andersen LB, Froberg K. Sources of variation in habitual physical activity of children and adolescents: The European Youth Heart Study. *Scand J Med Sci Sports* 2008; 18(3):298–308. PMID: 17555541. doi: 10.1111/j.1600-0838.2007.00668.x.
9. McCormack GR, Friedenreich C, Shiell A, Giles-Corti B, Doyle-Baker PK. Sex and age-specific seasonal variations in physical activity among adults. *J Epidemiol Commun Health* 2010;64:1010–16. PMID: 19843499. doi: 10.1136/jech.2009.092841.
10. Carson V, John SC, Cutumisu N, Boule N, Edwards J. Seasonal variation in physical activity among preschool children in a northern Canadian city. *Res Q Exerc Sport* 2010;81(4):392–99. PMID: 21268462. doi: 10.1080/02701367.2010.10599699.
11. Harrison F, Jones AP, Bentham G, van Sluijs EM, Cassidy A, Griffin SJ. 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* 2011;8:47. PMID: 21609441. doi: 10.1186/1479-5868-8-47.
12. Bélanger M, Gray-Donald K, O'Loughlin J, Paradis G, Hanley J. Influence of weather conditions and season on physical activity in adolescents. *Ann Epidemiol* 2009;19(3):180–86. PMID: 19217000. doi: 10.1016/j.annepidem.2008.12.008.
13. Colley R, Gorber SC, Tremblay MS. Quality control and data reduction procedures for accelerometry-derived measures of physical activity. *Health Rep* 2010;21(1):63–69. PMID: 20426228.
14. Freedson P, Pober D, Janz KF. Calibration of accelerometer output for children. *Med Sci Sports Exerc* 2005;37(11):S523–30. PMID: 16294115. doi: 10.1249/01.mss.0000185658.28284.ba.
15. Esliger DW, Tremblay MS. Technical reliability assessment of three accelerometer models in a mechanical setup. *Med Sci Sports Exerc* 2006; 38(12):2173–81.PMID:17146326.doi:10.1249/01.mss.0000239394.55461.08.
16. Troiano R, Berrigan D, Dodd K, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* 2008;40(1):181–88. PMID: 18091006. doi: 10.1249/mss.0b013e31815a51b3.
17. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE): Design and Methods. *BMC Public Health* 2013;13:900. PMID: 24079373. doi: 10.1186/1471-2458-13-900.
18. City of Saskatoon. Saskatoon Census Metropolitan Area, 2011. Available at: http://www.saskatoon.ca/DEPARTMENTS/Community%20Services/PlanningDevelopment/FutureGrowth/DemographicAndHousingData/Documents/2013%20Neighbourhood%20Profiles/saskatoon%20cma.pdf (Accessed May 14, 2014).
19. Muhajarine N. Planning for Growth in Saskatoon: Past, Present and Future, 2011. Available at: http://smartcitieshealthykids.com/wp-content/uploads/2013/04/Planning-for-Growth_FINAL_-Aug_20_2012.pdf (Accessed June 1, 2015).
20. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Rep* 2011;22(1): 15–23. PMID: 21510586.
21. Katapally TR, Muhajarine N. Towards uniform accelerometry analysis: A standardization methodology to minimize measurement bias due to systematic accelerometer wear-time variation. *J Sports Sci Med* 2014;13:379–86. PMID: 24790493.
22. Government of Canada. Daily Data Report for April 2010, 2010. Available at: http://climate.weather.gc.ca/climateData/dailydata_e.html?timeframe=2&

Prov=SASK&StationID=47707&dlyRange=2008-12-022014-01-19&Year=2010&Month=4&Day=01 (Accessed March 11, 2014).

23. Rainham DG, Smoyer-Tomic KE, Sheridan SC, Burnett RT. Synoptic weather patterns and modification of the association between air pollution and human mortality. *Int J Environ Health Res* 2005;15(5):347–60. PMID: 16416752. doi: 10.1080/09603120500289119.
24. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth: A review. *Am J Prev Med* 2011;41(4):442–55. PMID: 21961474. doi: 10.1016/j.amepre.2011.06.036.
25. Kaushal N, Rhodes RE. The home physical environment and its relationship with physical activity and sedentary behavior: A systematic review. *Prev Med* 2014;67:221–37. PMID: 25084562. doi: 10.1016/j.ypmed.2014.07.026.
26. Cillero IH, Jago R. Systematic review of correlates of screen-viewing among young children. *Prev Med* 2010;51:3–10. PMID: 20417227. doi: 10.1016/j.ypmed.2010.04.012.

Received: July 30, 2015
Accepted: November 5, 2015

RÉSUMÉ

OBJECTIFS : Les interventions de promotion de la vie active cherchent surtout à modifier l'aménagement urbain et le milieu bâti, mais les variations météorologiques, un phénomène qui interagit perpétuellement avec ces facteurs environnementaux, sont systématiquement sous-explorées. Notre étude vise à élaborer une méthode pour relier les données météorologiques aux données transversales existantes obtenues par accélérométrie pour capter les variations météorologiques.

MÉTHODE : Nous avons classé les quartiers de Saskatoon en quartiers à agencement quadrillé, en quartiers scindés à agencement quadrillé et en quartiers à agencement curviligne. Par la suite, nous avons utilisé 137 accéléromètres Actical pour recueillir des données sur l'activité physique d'intensité modérée à élevée (APIME) et le comportement sédentaire (CS) auprès de 455 enfants au cours de 25 cycles séquentiels d'une semaine entre avril et juin 2010. Ce déploiement séquentiel était nécessaire pour surmonter la différence de ratio entre la taille de l'échantillon et le nombre d'accéléromètres. Nous avons élaboré une méthode de maillage de données où chaque cycle d'accélérométrie était assorti aux conditions atmosphériques locales (propres à Saskatoon) selon Environnement Canada. Nous avons mené des analyses statistiques pour dépeindre l'influence de l'aménagement urbain sur l'APIME et le CS après la prise en compte des conditions atmosphériques locales.

RÉSULTATS : L'intégration de l'accélérométrie transversale et des conditions atmosphériques locales a permis de saisir les variations météorologiques au cours d'une même transition saisonnière. Globalement, durant la transition du printemps à l'été à Saskatoon, l'APIME a augmenté et le CS a diminué les jours les plus chauds. Après la prise en compte des conditions météorologiques locales, nous avons observé à plusieurs reprises que les enfants vivant dans les quartiers scindés à agencement quadrillé présentaient cumulativement une APIME significativement plus faible et un CS significativement plus élevé.

CONCLUSION : La méthode proposée pourrait servir à relier des données transversales obtenues par accélérométrie disponibles mondialement et des données météorologiques propres à un lieu pour comprendre comment le milieu bâti et les facteurs de l'environnement social interagissent avec diverses conditions atmosphériques pour influencer la vie active.

MOTS CLÉS : temps météorologique; activité physique; mode de vie sédentaire