Seasonal Changes in Preschoolers' Sedentary Time and Physical Activity at Childcare

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Abstract: *Background*: This investigation evaluated seasonal changes in preschoolers' (3-5 years) sedentary time and physical activity (PA) during childcare.

Methods: Sixty-two children from 4 preschools in Fargo, North Dakota had their sedentary behavior and PA objectively assessed during 2 separate weeks of childcare. Children wore accelerometers for 5 consecutive days, once each in the fall (October/November) and winter (January/February). Separate analyses were conducted to evaluate seasonal changes in full-day, indoor only, and outdoor only sedentary time and PA during childcare.

Results: When expressed relative to accelerometer wear time, the full-day rate of sedentary time accumulation (minutes/hour) increased significantly from fall to winter ($p < 0.001$), while accumulation rates for all other PA variables (light PA, moderate PA, moderate-to-vigorous PA, and activity counts) significantly declined during this period (all p's < 0.001). No significant changes in accumulation rates for sedentary time or PA (light PA, moderate PA, moderate-to-vigorous PA, and activity counts) were noted for either indoor or outdoor time between seasons.

Conclusions: Childcare-related sedentary time and PA can dramatically vary across seasons.

Keywords: Accelerometry, physical activity, pediatrics, public health, childcare.

INTRODUCTION

The prevalence of obesity among 2 to 5 year-old children in the United States (US) has more than doubled over the last 4 decades [1]. This increase in obesity prevalence is particularly worrisome as higher levels of adiposity during childhood are associated with greater risks for hypertension, hyperlipidemia, and diabetes [2]. In light of these concerns, limiting time spent in sedentary behaviors and increasing physical activity (PA) have been identified as primary childhood obesity prevention measures [3-5]. An important location where many US preschoolers' accumulate daily PA is the childcare setting, as approximately 61% of American children 0-6 years old receive non-parental childcare on a regular basis [6]. Previous research using objective monitoring methods has demonstrated that PA levels during childcare are typically low with most studies reporting an average of less than 60 minutes of moderate-to-vigorous PA (MVPA) per every 8 hours in childcare [7-15].

Many external factors may influence a child's ability to be physically active. Seasonal variations in PA may result from changes in temperature, precipitation, and daylight hours [16]. Specifically, windy and cold-weather climates typically experienced in the Northern US, Europe, and parts of Canada may act as an impediment to PA [17]. Results from several objective monitoring studies at northern latitudes have indicated that preschoolers' PA levels tend to be higher during warmer seasons than cooler seasons [18-20]. However, it remains unknown how sedentary behavior and PA within the childcare setting may change across seasons.

Therefore, the purpose of this study was to prospectively track preschoolers' accelerometer-measured sedentary behavior and PA during childcare while investigating for seasonal differences in these variables between the fall and winter months in Fargo, North Dakota. Due to this location's potential for extreme seasonal temperature variation (e.g. mean daily temperature: January = -12.7 °C, April = 6.7 °C, July = 21.6 °C, October = 7.4 °C) [21], we hypothesized that sedentary time and PA would significantly change from fall to winter among preschoolers in this sample.

METHODS

Study Design and Setting

Children from 4 childcare centers were recruited to participate in this study. The study was conducted over

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a 4-month period with PA assessments in the childcare setting occurring in October/November 2011 (fall) and 12 weeks later in January/February 2012 (winter). All assessments were completed within a 3 week period at each time point.

The study protocol was approved by the North Dakota State University – Institutional Review Board before recruitment began. Parents of preschoolers (3-5 years old) at the 4 childcare centers were given a letter introducing and describing the study. A research team member then attended each childcare center for an informational session to answer questions from parents and to provide them with informed consent packets. Only children whose parents returned signed informed consent packets were allowed to participate.

Participants

Informed consent packets for 80 children were signed by parents and returned before the start of the study. Five children were excluded from participating for not meeting the age requirement (3-5 years old). A total of 75 children (40 boys, 35 girls) participated in the study. The sample was comprised of primarily Caucasian children (89.3%) with smaller proportions of mixed-race (6.7%), African-American (2.7%), Hispanic (1.3%), and Native American children (1.3%).

Anthropometric Assessment

Height and weight for all participating children were measured prior to the first PA assessment. Height was measured to the nearest 0.01 cm using a portable stadiometer (Seca Road Rod, #214; Seca GmbH & Co. KG., Hamburg, Germany). Weight was measured to the nearest 0.1 kg using a portable digital scale (Tanita TBF-300A; Tanita Corporation, Tokyo, Japan). Body mass index (BMI) was calculated by dividing weight by height squared ($kg \cdot m^{-2}$). Sex- and age-specific Centers for Disease Control and Prevention growth charts were used to classify participants based upon BMI score as non-overweight (BMI < 85^{th} percentile), overweight (85^{th} percentile ≤ BMI < 95^{th} percentile), or obese (BMI ≥ 95^{th} percentile) [22, 23].

Sedentary Time and Physical Activity Assessment

Childcare-related sedentary time and PA were objectively assessed using an ActiGraph accelerometer (ActiTrainer model; Actigraph LLC, Pensacola, FL). Previous research has demonstrated that the ActiGraph has acceptable reliability and validity for quantifying PA in preschool aged children [24, 25]. Short time sampling intervals are generally recommended for accelerometry assessments among preschoolers [26] because children's PA can be highly sporadic with the vast majority of moderate- or higher-intensity activities occurring in bouts lasting less than 10 seconds [27, 28]. Therefore, a 5 second data collection epoch was chosen for use in this study to better capture the intermittent PA patterns of preschoolers [29].

Preschoolers were asked to wear an accelerometer while at childcare for 5 days (Monday through Friday) during the fall and winter assessments. A trained research assistant fitted each child with an elastic waist belt and attached accelerometer upon arrival at the childcare center. Accelerometers were positioned over the right hip. The research assistant removed the accelerometers as children left the childcare center each day. Time of arrival and departure, beginning and ending of naptime, and time spent outdoors was recorded daily for each child. To ensure accurate time recording, childcare centers were provided with electronic clocks synchronized with the accelerometers. Devices were collected at the end of the week. Accelerometer data were downloaded onto a laboratory computer using ActiLife (version 4.3.0; ActiGraph LLC, Pensacola, FL). To reduce the influence of interdevice variability on sedentary time and PA measurements, children wore the same accelerometer at both assessment periods.

Seasonal Weather Data

Dry bulb temperature (air temperature) and liquid equivalent precipitation were measured during each data collection period. Temperature and precipitation data were retrieved from the National Climatic Data Center webpage [30]. Mean temperature and total precipitation from 7 a.m. to 6 p.m. was computed for each assessment day. This time interval encompassed the earliest start time and latest closing time among the 4 participating childcare centers. All participating childcare centers were located within a 7.5 mile straight-line distance of the station where weather observations were conducted.

Data Processing

Raw accelerometer data were processed using the "PhysicalActivity" package in R version 2.15.2 (R Development Core Team, R Foundation for Statistical Computing, Vienna, Austria) [31]. Accelerometer non-wear time was identified as any interval of consecutive zero activity counts ≥ 10 minutes. Wear time was derived by subtracting non-wear time from the total duration of each child's daily attendance at childcare (excluding naptime). Days with at least 180 minutes of wear time were considered valid. For the analyses presented herein, participants with at least 2 or more valid days at each assessment period (fall and winter) were retained.

Each epoch of valid wear time was characterized as sedentary (0-37 counts/15 seconds), light PA (LPA; 38-419 counts/15 seconds), moderate PA (MPA; 420-841 counts/15 seconds), or MVPA (≥ 420 counts/15 seconds) [24, 32, 33]. Activity count ranges for sedentary time, LPA, MPA, and MVPA were divided by 3 to accommodate the 5 second recording epoch used in this study. Daily totals (minutes) for each PA classification were calculated by counting the number of epochs within the same intensity category and dividing by 12. Total daily activity counts (counts/day) during childcare were calculated by summing activity counts across all epochs of daily wear time. Sedentary time, LPA, MPA, MVPA, and activity counts were also expressed relative to wear time (minutes/hour or counts/minute) to account for the varying lengths of time children spent in childcare. Indoor and outdoor values for sedentary time and all PA variables were calculated using the recorded starting and ending times for outdoor activities. Totals for all PA variables were averaged across days at each assessment period.

Statistical Analyses

Descriptive statistics were calculated to describe the sample. A paired *t*-test was used to examine for mean changes in temperature from fall to winter. The Wilcoxon signed-rank test was used to examine for changes in fall to winter precipitation as this variable showed evidence of non-normality. Seasonal changes in sedentary time and PA were evaluated using a series of fixed effects ANCOVA models [34]. Change scores for all sedentary time and PA variables were regressed upon a set of k-1 (k = number of preschools) centered indicator variables to identify each child's preschool membership. The resulting intercept from the fitted model represented the main effect of time (fall to winter change). Separate models were fit to examine for changes in full-day, indoor only, and outdoor only childcare-related sedentary time and PA. All statistical analyses were conducted using R (version 2.15.2). The level of significance α was set at 0.05 for the temperature and precipitation analyses. Due to the large number of sedentary time and PA analyses conducted, we employed a Bonferroni-correction to control the global type I error rate at $\alpha = 0.05$ for the 11 hypothesis tests within the 3 separate full-day, indoor only, and outdoor only analyses. Therefore, statistical significance was defined as $p \leq 0.05/11 = 0.0045$ for each set of 11 hypothesis tests.

RESULTS

Compliance and Sample Characteristics

Sixty-two of the original 75 children who participated in the study met wear time requirements during the fall and winter data collection periods (82.7% with complete data). Four participants were lost to follow-up and no longer attending the childcare centers during the winter assessment period. Data from another 5 children were excluded due to accelerometer malfunction. Another 4 children were excluded for not meeting wear time requirements at both data collection periods. The 62 children meeting compliance criteria averaged (M ± *SD*) 4.4 ± 0.9 valid days of

Table 1: Descriptive Characteristics of Participating Children Meeting Compliance Criteria

Characteristic	Boys (*n* = 35)	Girls (*n* = 27)	Total (*N* = 62)
Age (years)	4.2 ± 0.6	4.4 ± 0.7	4.3 ± 0.7
Height (cm)	107.0 ± 5.9	105.7 ± 6.9	106.5 ± 6.4
Weight (kg)	18.5 ± 2.7	18.6 ± 4.0	18.4 ± 3.3
BMI ($kg•m^{-2}$)	16.1 ± 1.1	16.3 ± 2.0	16.2 ± 1.5
Weight status (%)			
Non-overweight	85.7	62.9	75.8
Overweight	8.6	18.5	12.9
Obese	5.7	18.5	11.3

Note. Values for age, height, weight, and BMI are presented as M ± *SD*.

accelerometer wear time in fall and 4.4 ± 0.9 valid days in winter. Descriptive characteristics of children meeting compliance criteria are presented in Table **1**.

Temperature and Precipitation Changes

Mean (± *SD*) outside temperature during preschool hours (7 a.m. to 6 p.m.) declined from 2.9 ± 4.8 °C in fall to -8.9 ± 8.6 °C in winter ($t = 4.52$, $p < 0.001$). No significant changes in liquid equivalent precipitation were observed from fall (0.3 ± 0.9 mm) to winter (0.1 ± 0.2 mm).

Full-Day Changes in Childcare-Related Activity

Means for full-day accelerometer wear time, sedentary time, and PA during childcare in fall and winter are presented in Table **2**. Full-day accelerometer wear time and sedentary time did not significantly change from fall to winter. Absolute levels of LPA, MPA, MVPA, and activity counts all significantly decreased from fall to winter. When expressed relative to accelerometer wear time, the rate of sedentary time accumulation (minutes/hour) increased significantly from fall to winter, while accumulation rates for all other PA variables (LPA, MPA, MVPA, and activity counts) significantly declined during this period.

Indoor Changes in Childcare-Related Activity

Means for indoor accelerometer wear time, sedentary time, and PA during childcare in fall and winter are presented in Table **3**. Indoor accelerometer wear time and absolute levels of sedentary time significantly increased from fall to winter. No significant changes in absolute levels of LPA, MPA, or MVPA were observed from fall to winter. After expressing sedentary time and PA relative to total accelerometer wear time, no significant fall to winter changes in the accumulation rates of sedentary time, LPA, MPA, MVPA, or activity counts were noted.

Outdoor Changes in Childcare-Related Activity

Means for outdoor only accelerometer wear time, sedentary time, and PA during childcare in fall and winter are presented in Table **4**. Outdoor accelerometer wear time and absolute levels of sedentary time and PA (LPA, MPA, MVPA, and activity counts) all significantly decreased from fall to winter. After expressing sedentary time and PA relative to total accelerometer wear time, no significant fall to winter changes in the accumulation rates for sedentary time, LPA, MPA, MVPA, or activity counts were observed.

Table 2: Full-Day Sedentary Time and Physical Activity During Fall and Winter at Childcare (*N* = 62)

Variable	Fall (M ± *SE*)	Winter (M ± *SE*)	*F**	*p*†
Activity duration (minutes/day)				
Accelerometer wear time	319.8 ± 5.5	305.7 ± 6.0	5.77	0.0195
Sedentary time	178.3 ± 3.5	186.3 ± 3.6	4.78	0.0328
LPA	90.9 ± 2.3	80.1 ± 2.5	20.27	< 0.0001
MPA	31.7 ± 1.2	24.3 ± 1.1	48.77	< 0.0001
MVPA	50.5 ± 2.2	39.3 ± 2.0	43.78	< 0.0001
Absolute activity level (counts/day)				
Activity counts	237,539 ± 9,375	194,115 ± 8,934	33.62 < 0.0001	
Activity accumulation rate (minutes/hour)				
Sedentary time	33.7 ± 0.5	37.0 ± 0.5	55.88	< 0.0001
LPA	16.9 ± 0.3	15.5 ± 0.3	25.71	< 0.0001
MPA	5.9 ± 0.2	4.6 ± 0.2	73.73	< 0.0001
MVPA	9.4 ± 0.3	7.5 ± 0.3	61.44	< 0.0001
Relative activity level (counts/minute)				
Activity counts	733 ± 22	619 ± 21	46.24	< 0.0001

Note. LPA = light physical activity; MPA = moderate physical activity; MVPA = moderate-to-vigorous physical activity.
**F*-values correspond to test for fall to winter change from fixed effects ANCOVA models.
†significance defined as $p \leq 0.05/11 = 0.0045$ for each set of 11 full-day hypothesis tests.

Table 3: Indoor only Sedentary Time and Physical Activity During Fall and Winter at Childcare (*N* = 62)

Variable	Fall (M ± *SE*)	Winter (M ± *SE*)	*F**	*p*†
Activity duration (minutes/day)				
Accelerometer wear time	256.2 ± 4.2	285.4 ± 5.8	25.98	< 0.0001
Sedentary time	157.3 ± 2.9	180.0 ± 3.6	37.98	< 0.0001
LPA	67.0 ± 2.0	72.0 ± 2.4	5.43	0.0233
MPA	19.9 ± 0.9	20.5 ± 1.0	0.49	0.4884
MVPA	31.9 ± 1.6	33.4 ± 1.8	1.14	0.2896
Absolute activity level (counts/day)				
Activity counts	157,166 ± 7,038	168,460 ± 8,196	2.69	0.1061
Activity accumulation rate (minutes/hour)				
Sedentary time	37.5 ± 0.5	38.3 ± 0.5	2.65	0.1092
LPA	15.3 ± 0.3	14.9 ± 0.3	1.94	0.1689
MPA	4.5 ± 0.1	4.2 ± 0.2	5.96	0.0178
MVPA	7.2 ± 0.3	6.8 ± 0.3	2.40	0.1268
Relative activity level (counts/minute)				
Activity counts	591 ± 19	577 ± 21	0.74	0.3919

Note. LPA = light physical activity; MPA = moderate physical activity; MVPA = moderate-to-vigorous physical activity.
**F*-values correspond to test for fall to winter change from fixed effects ANCOVA models.
†significance defined as $p \leq 0.05/11 = 0.0045$ for each set of 11 indoor only hypothesis tests.

Table 4: Outdoor only Sedentary Time and Physical Activity During Fall and Winter at Childcare (*N* = 62)

Variable	Fall (M ± *SE*)	Winter (M ± *SE*)	*F**	*p*†
Activity duration (minutes/day)				
Accelerometer wear time	63.6 ± 2.6	20.3 ± 1.3	279.40	< 0.0001
Sedentary time	21.0 ± 1.3	6.3 ± 0.4	147.20	< 0.0001
LPA	23.9 ± 1.0	8.1 ± 0.6	236.03	< 0.0001
MPA	11.8 ± 0.6	3.8 ± 0.3	192.33	< 0.0001
MVPA	18.7 ± 1.1	5.9 ± 0.4	163.01	< 0.0001
Absolute activity level (counts/day)				
Activity counts	80,373 ± 4,370	25,655 ± 1,794	172.08	< 0.0001
Activity accumulation rate (minutes/hour)				
Sedentary time	20.3 ± 0.7	18.9 ± 0.5	3.74	0.0580
LPA	22.4 ± 0.4	23.8 ± 0.4	8.34	0.0054
MPA	10.9 ± 0.4	11.3 ± 0.3	0.67	0.4161
MVPA	17.3 ± 0.6	17.3 ± 0.6	0.01	0.9651
Relative activity level (counts/minute)				
Activity counts	1,244 ± 41	1,251 ± 37	0.04	0.8515

Note. LPA = light physical activity; MPA = moderate physical activity; MVPA = moderate-to-vigorous physical activity.
**F*-values correspond to test for fall to winter change from fixed effects ANCOVA models.
†significance defined as $p \leq 0.05/11 = 0.0045$ for each set of 11 outdoor only hypothesis tests.

DISCUSSION

This study examined preschoolers' patterns of childcare-related sedentariness and PA across the fall and winter seasons in a northern tier US state. In agreement with our hypothesis, significant fall to winter changes were observed in preschoolers' sedentary time (minutes/hour) and time spent in all intensities of PA (minutes/day and minutes/hour) during the full preschool day. Substantial declines in outdoor temperature (≈ 12 °C) were also observed during this period. Concurrent with changes in outdoor temperature, time spent outdoors during childcare declined by more than 60% from fall to winter, which was accompanied by significant declines in absolute levels of outdoor sedentary time (70% decline) and PA (66-68% declines across all intensities). However, declines in childcare-related outdoor activity appear to be explained by decreases in total time spent outdoors, as the rate of activity accumulation for outdoor sedentary time and all intensities of PA did not significantly change across seasons when expressed relative to accelerometer wear time. In comparison to time spent outdoors, less variability in indoor activity was observed as only absolute estimates of indoor sedentary time (minutes/day) during childcare changed from fall to winter.

Due to this study's observational design, cause and effect relationships between the observed decline in temperature and changes in childcare-related sedentary time and PA cannot be established. However, reductions in outside temperature did cause each childcare center to suspend all outdoor activity time in accordance with center policies (no outdoor activity allowed at temperatures < -17.7 °C) for at least 1 day during the winter assessment period. This practice is not uncommon in cold climates throughout the US, with such policies and regulations potentially limiting time spent outdoors during winter compared to warmer months. Evidence from this study would suggest that such reductions in outdoor time may have substantial impacts on childcare-related PA as outdoor and full-day MVPA among children in this study decreased by approximately 13 minutes/day and 11 minutes/day, respectively. This finding is consistent with previous research among preschoolers which has shown that time spent outdoors is significantly related to overall PA [35].

Previous work by Fisher and colleagues [19] demonstrated seasonal variability in preschoolers' sedentary time, as the percentage of monitored time spent sedentary among a cross-sectional sample of 209 children (mean age = 4.8 years) was significantly higher among children assessed during spring (79.5%) than among those assessed in summer (74.2%) or fall (76.1%). Results from our longitudinal investigation demonstrated a significant fall to winter increase in the rate of sedentary time accumulation (+3.3 minutes/hour) during the full-day at childcare. This increase appears largely influenced by the significant increase in time spent indoors (+29 minutes/day) which had a higher rate of sedentary time accumulation than time spent outdoors. The biological significance of such increases in sedentary time remains unknown. Moreover, because sedentary behavior was not assessed outside of childcare, we cannot speculate how sedentary time changed (or did not change) in other settings. Regardless, among adults, higher levels of sedentariness have been independently associated with increased risks for obesity [36], cardiovascular disease [37, 38], diabetes [36], the metabolic syndrome [39], and all-cause mortality [37]. More research is needed to clarify whether or not the same relationships between sedentary behavior and negative health consequences exist among younger individuals such as preschoolers.

Previous cross-sectional analyses have reported seasonal variability in preschoolers' accelerometer-measured PA at northern latitudes [18-20, 40]. In a cross-sectional analysis of 437 preschoolers in New York City, Rundle and colleagues [20] noted that PA was significantly greater among those assessed between May and September in comparison to those measured between October and April. Similarly, a cross-sectional investigation by Burdette and colleagues [18] reported seasonal variability in preschoolers' accelerometer-measured PA, with the lowest PA levels occurring in winter (December through February) and the highest in autumn (September through November) among a sample of 250 children in Cincinnati, Ohio. Finn *et al*. [40] also reported seasonal variability in preschoolers' PA among a cross-sectional sample of 214 children in South Dakota, as mean activity counts/minute were significantly higher in fall than summer between the hours of 9 a.m. and 5 p.m. (assumed to represent the period when most children were at childcare). Lastly, Fisher and colleagues [19] reported seasonal variability in preschoolers' PA among a cross-sectional sample of 209 children in Scotland, with levels of PA being higher in the summer, fall, and winter than during spring. Cumulatively, evidence from these cross-sectional investigations suggests that preschoolers' PA at northern latitudes (all referenced study locations at latitudes > 39° N) can vary across seasons. However, synthesizing these findings into a meaningful context regarding the magnitude with which preschoolers' PA may seasonally vary is difficult due to the various accelerometers used (Actiwatch [20, 40], RT3 [18], ActiGraph[19]) and the design limitations of the aforementioned studies (i.e. cross-sectional designs). Results presented herein suggest that seasonal variation in childcare-related PA at northern latitudes can be substantial, as absolute levels of full-day MVPA and total activity (activity counts) during childcare decreased by 22% and 18%, respectively, while total monitoring time did not significantly change during this period.

While the present study provides valuable information to the empirical literature base, it is not without limitations. The primary limitation of this study was that sedentary behavior and PA were measured solely in the childcare setting. As such, our measurements do not reflect any activity which may have occurred outside of childcare. The observed fall to winter changes in sedentary time and PA during childcare may or may not have been reflected in other settings (e.g. at home). However, our goal and primary objective was to measure and quantify changes in activity which occurred in the childcare setting and not during the entire day in all settings. Another limitation worth noting relates to the research design of this study, as all collected data were from a small geographic region in eastern North Dakota, which limits the generalizability of our results to larger geographic areas or regions. Also, PA was only measured during fall and winter, so we are unable to make determinations as to how PA levels may change or vary during summer and spring. Moreover, due to the small number of preschools (4) participating in this investigation, we chose to use a fixed effects ANCOVA model when examining for seasonal changes in sedentary time and PA which limits our inferences only to the sample of schools assessed. As such, we can make no judgments regarding the levels and/or changes in sedentary behavior and PA at other preschools outside of our sample.

CONCLUSIONS

Results from this investigation indicate that childcare-related sedentary time and PA can dramatically vary across seasons. Among preschoolers in this sample, children tended to be more sedentary and less physically active at childcare during winter than fall. However, the childcare-related increases in sedentary time and declines in PA observed in this study appear to be largely the result of reductions in time spent outdoors, which was likely influenced by reductions in outside temperature. Future investigations are needed to clarify the role of other climatic forces such as rain, wind, etc. on preschool children's sedentary behavior and PA. The reduction of outdoor time and related PA observed in this study provides a further rationale for the development of novel interventions to increase preschoolers' childcare-related PA levels in indoor settings (i.e. preschool classroom).

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