Influence of Weather Conditions and Season on Physical Activity in Adolescents

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PURPOSE: Little is known about how seasonal variation in physical activity relates to declining physical activity in adolescence. We quantified how each of daily weather conditions and season affect physical activity during adolescence.

METHODS: We followed 1293 students, initially aged 12 to 13 years over 5 years. Participants completed a 7-day physical activity recall checklist every 3 months. Data on daily weather conditions were obtained from Environment Canada. The association between the number of physical activity sessions per day, and each of season, and daily weather conditions was assessed in Poisson regressions.

RESULTS: Adjusting for age, sex, and month, the average number of physical activity sessions per day was 2% to 4% lower for every 10 mm of rainfall and 1% to 2% higher for every 10 °C increase in temperature. Although every 10 cm of snow accumulation was associated with 5% higher activity rates, days with snowfall had lower physical activity. Physical activity was lower during winter and increased during warmer months. However, the warm-month increases did not compensate for winter decreases so that activity decreased by 7% yearly.

CONCLUSIONS: Declines in physical activity during adolescence may be partly explained by declines during winter. Increasing opportunities for physical activity during poor weather, in particular during winter, may mitigate declines in physical activity during adolescence.

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KEY WORDS: Adolescence, Cohort, Physical Activity, Season, Weather.

INTRODUCTION

Although average physical activity levels of youth are already below recommendations worldwide (1), children generally go through a period marked by a sharp decrease in participation in physical activity when they become adolescents (2, 3). Studies that describe this decline and identify factors that influence physical activity are needed to develop evidence-based public health practices that help youth maintain healthy levels of physical activity. Although some reports indicate that physical activity levels decrease during winter and increase in summer (4–8), few population-based interventions take seasonal differences into account (9).

Potential consequences of seasonal variation in physical activity levels include decreases in fitness levels, but also the possibility of acquiring an increasingly sedentary lifestyle since periods of infrequent participation in physical activity are linked to becoming physically inactive (10, 11). However, little is known about how lower physical activity levels during winter relate to declines in physical activity participation during adolescence. Moreover, we have little information on factors that relate to less activity during winter. Seasonal variation in physical activity may be the result of changes in weather conditions. Several studies among adults report that poor weather is perceived as a barrier to the practice of physical activity (12–14) and that daily physical activity levels increase as ambient temperature rises, and decrease with rain and snowfall (15, 16). However, seasonal variation in physical activity levels have been noted in locations with little variation in weather conditions between seasons (4, 8, 17), suggesting that weather may not be the only determinant of seasonal change in physical activity levels.

Unlike most known determinants of physical activity, weather conditions can change rapidly and could therefore contribute to explaining short-term (daily) as well as long-term (seasons) variation in physical activity levels. Because
selected Abbreviations and Acronyms
NDIT = Natural History of Nicotine Dependence in Teens study
SD = standard deviation
IQR = interquartile range
CI = confidence interval

even a few days of increased physical activity are linked to beneficial health outcomes, increased understanding of factors explaining short-term variation in physical activity is needed (18, 19). The value of both sustained and short-term participation in physical activity is recognized in several national and international guidelines, with the recommendation that physical activity be practiced almost every day (1, 20–25).

Considering that health outcomes can be influenced by both habitual and short term physical activity, the links between physical activity level, season, and weather deserve further attention. To our knowledge, there are no studies that describe how seasonal variation in physical activity relates to declining physical activity levels during adolescence or how weather conditions affect daily physical activity participation in this population. In this analysis we examined the effect of season and daily weather conditions on physical activity over 5 years during adolescence.

MATERIAL AND METHODS
Study Population
Data for this analysis were obtained from the Natural History of Nicotine Dependence in Teens (NDIT) study, a prospective study of 1,293 students initially aged 12 to 13 years. Students were recruited from grade 7 classes in a convenience sample of 10 Montreal secondary schools. Schools were selected to include a mix of French and English language schools; urban, suburban, and rural schools; as well as schools located in high, moderate, and low socioeconomic neighborhoods. All subjects and a parent or guardian provided signed informed consent. Data collection began in the fall of 1999 and was repeated every 3 months during the 10-month school year for 5 years, for a total of 20 survey cycles. Participants completed self-report questionnaires in French or English, in a classroom or as a larger group in the school cafeteria. Data collectors visited schools twice during each survey cycle, so that participants who were absent on the first day could complete the questionnaire on the second day. The study received approval from the McGill University Institutional Review Board.

Study Variables

Moderate and vigorous physical activity. The number of physical activity sessions per day was measured in a 7-day recall similar to those used in other large-scale studies (10). It was adapted from the Weekly Activity Checklist (26) to reflect common activities engaged in by adolescents in Montreal. Specifically, the following item was repeated at every survey cycle: “Think about the physical activities that you did last week from Monday to Sunday outside your regular school gym class. For each activity that you did for 5 minutes or more at one time, mark an ‘X’ to show the day(s) on which you did that activity...,” followed by a list of 29 activities. At every survey cycle, respondents checked activities participated in on each day of the previous week. The 3-day test-retest reliability of the original instrument was \( r = 0.74 \) and it correlated with an accelerometer at \( r = 0.34 \) (26). In addition, scores on the physical activity recall correlated strongly with energy intake (27). This current analysis focused on activities of moderate and vigorous intensity because, compared with light intensity activities, they are associated with considerably more health benefit (28). As suggested in the U.S. Surgeon General Report (29), activities with estimated energy costs greater than or equal to 4.8 metabolic equivalent values were categorized as moderate or vigorous. The 23 activities retained based on this criterion can be described as leisure-time or discretionary physical activities. They included bicycling, swimming/diving, basketball, baseball/softball, football, soccer, racquet sports (badminton/tennis), hockey (ice or ball), jump rope, downhill skiing/snowboarding, cross-country skiing, ice skating, rollerblading/skateboarding, exercise/physical conditioning, ball-playing, track and field, games (chase, tag, hopscotch), ballet (jazz or classical), outdoor play, martial arts (karate, judo, tai chi, kung fu), boxing/wrestling, jogging, and running. Because NDIT data were collected during the academic school year (i.e., from September to June), data for the 7-day recall were not available for July or August.

Community physical activity. Participation in organized community physical activity was measured by: “Think about sports teams and lessons outside of school. In the past 3 months, did you belong to a... basketball, soccer, football, swimming, baseball, volleyball, hockey, ballet/dance, aerobics, ski, judo/karate, other (name them) team/lessons?” Respondents checked yes or no for each activity. Because participation in organized community sports was measured in a 3-month recall, data for this variable were available for all seasons, including summer.

Season. In Montreal, normal daily average temperatures range from \(-5^\circ C\) to \(20^\circ C\) in spring, \(12^\circ C\) to \(28^\circ C\) in summer, \(-2^\circ C\) to \(20^\circ C\) in fall, and \(-15^\circ C\) to \(-12^\circ C\) in winter (30). We defined winter as covering the period from December to February, spring as covering the period from March to June, and fall as covering the period from...
September to November. We added the category summer for analyses on community physical activity.

**Weather conditions.** Data on daily mean temperature (in degrees centigrade), total rainfall (in millimeters), total snowfall (in centimeters), and ground accumulation of snow (in centimeters) were retrieved from publicly accessible files on the Environment Canada Web site (31) for weather conditions reported from the Pierre Elliott Trudeau International Airport weather station. We assumed that these data were applicable to all participants because all participating schools were located within 50 kilometers of the airport weather station, and all were at an elevation within 25 meters of the elevation of the weather station.

**Data Analysis**

Dates (i.e., day, month, and year) were used to merge data on daily weather condition with data on daily physical activity. Of 131,629 observations, 127,779 (97%) had all covariates and were analyzed. The association between number of physical activity sessions per day and each of season and daily weather conditions was investigated using Poisson regression models (32). Analyses were conducted to test the effects of season, month, and each weather condition separately. We then examined all exposure variables in multivariate models that were stratified by season since snowfall and ground accumulation of snow were only relevant in winter. We used two-level models to account for the non-independence of repeated observations of the same individual, and we took clustering at the school level into account by using indicator variables for schools. All models included sex and age (to account for the effect of time). The potential for effect modification by sex was assessed by including interaction terms between sex and each of temperature, rainfall, snowfall, and accumulated snow. We also tested age-weather interaction terms to assess whether the influence of weather conditions differed by age. Analyses were performed by means of the SAS NLMIXED procedure (SAS Institute Inc, Cary, NC).

**RESULTS**

Of 2,300 eligible students, 1,293 (56%) agreed to participate, and 94% of those eligible completed questionnaires at each follow-up. The average age of participants at baseline was 12.8 (standard deviation, 0.6) years and 53% were girls. Data on past-week moderate and vigorous physical activity participation were available for a median (interquartile range [IQR]) of 18 (11-19) time points per participant. On average, over the 20 survey cycles, participants reported engaging in a median of 1 (0-3) moderate or vigorous physical activity session per day. Number of weekly physical activity sessions declined by an average of 7.2% (95% confidence interval [CI] = −7.5% to −6.9%) per year for boys and girls. On average, girls reported 14.5% (95% CI = −14.5% to −12.9%) fewer physical activity sessions per week than boys.

**Seasonal Differences in Physical Activity**

The number of reported physical activity sessions differed according to the time of year. Compared to winter, physical activity rates were 10.8% higher in spring (95% CI = 9.6% to 12.0%) and 11.4% higher in fall (95% CI = 10.1% to 12.8%) (Table 1). Differing rates of physical activity were also recorded for different months. The monthly changes in physical activity followed a continuous pattern of variation through the year and differences in rates of physical activity could be noticed among months of the same season (which led us to include month of year in further analyses, stratified by season).

The seasonal variation in physical activity is apparent in Fig. 1. Participation generally decreased during the winter months and increased during the warmer months. However, the warm-month increase was not sufficient to bring the number of physical activity sessions back to levels engaged in the preceding year. This resulted in a 32% reduction in daily number of moderate or vigorous physical activity sessions over the 5-year study. The amplitude of the seasonal variation (i.e., the difference between the highest and lowest monthly average number of moderate/vigorous physical activity sessions per day) nevertheless became smaller

**TABLE 1.** Percentage differences in physical activity levels according to seasons, month, and weather conditions

<table>
<thead>
<tr>
<th>Reference category/value</th>
<th>Index category/value</th>
<th>Difference*</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>Winter</td>
<td>† 11%</td>
<td>10% to 12%</td>
</tr>
<tr>
<td>Winter</td>
<td>Fall</td>
<td>† 11%</td>
<td>10% to 13%</td>
</tr>
<tr>
<td>Month</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>January</td>
<td>‡ 5%</td>
<td>−8% to −2%</td>
</tr>
<tr>
<td>December</td>
<td>February</td>
<td>‡ 2%</td>
<td>−7% to 3%</td>
</tr>
<tr>
<td>December</td>
<td>March</td>
<td>≤−4%</td>
<td>5% to 5%</td>
</tr>
<tr>
<td>December</td>
<td>April</td>
<td>† 18%</td>
<td>13% to 24%</td>
</tr>
<tr>
<td>December</td>
<td>May</td>
<td>† 17%</td>
<td>12% to 23%</td>
</tr>
<tr>
<td>December</td>
<td>June</td>
<td>† 19%</td>
<td>5% to 35%</td>
</tr>
<tr>
<td>December</td>
<td>September</td>
<td>† 11%</td>
<td>5% to 17%</td>
</tr>
<tr>
<td>December</td>
<td>October</td>
<td>† 10%</td>
<td>5% to 16%</td>
</tr>
<tr>
<td>December</td>
<td>November</td>
<td>≤−5%</td>
<td>5% to 5%</td>
</tr>
<tr>
<td>Mean temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>+10 °C</td>
<td>† 6%</td>
<td>5% to 6%</td>
</tr>
<tr>
<td>Rainfall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>+10 mm</td>
<td>≤−1%</td>
<td>1% to 1%</td>
</tr>
<tr>
<td>Snowfall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>+10 cm</td>
<td>† 11%</td>
<td>−13% to −9%</td>
</tr>
<tr>
<td>Snow on ground</td>
<td>December</td>
<td>† 3%</td>
<td>−5% to −2%</td>
</tr>
</tbody>
</table>

CI = confidence interval. † = increase. ‡ = decrease. ≤ = no difference.

*Adjusted for school, age, and sex.

†Percentage difference derived from Poisson regression rate ratio. Alternatively, the percentage difference for winter can be interpreted as a rate ratio of 1.11 with 95% CI = 1.10 to 1.12.
over time. In boys, these differences were 1.9, 1.1, 0.7, 0.6, and 0.5 sessions per day in years 1 to 5, respectively. In girls, they were 1.3, 1.0, 0.7, 0.4, and 0.4 in years 1 to 5.

Weather Conditions and Daily Physical Activity

Weather conditions had modest, but significant, effects on daily number of physical activity sessions engaged in. For every 10 °C increase in mean temperature, the number of moderate or vigorous physical activity sessions per day (95% CI) was 5.8% (5.3% to 6.2%) higher, after adjustments for school, sex, and age. In contrast, the rate of physical activity was 11.2% (13.1% to 9.3%) lower for each 10 cm of snowfall and 3.0% (3.5% to 2.4%) lower for every 10 cm of snow accumulated on the ground.

Weather Conditions and Daily Physical Activity Within Seasons

Regardless of season, adolescents were slightly more physically active on warmer days and on days with no rain (Table 2). The rates of physical activity participation were 2% to 4% lower for every 10 mm of rainfall and were 1% to 2% higher for every 10 °C increase in temperature. In winter, the chances of taking part in additional physical activity sessions decreased on snowy days but were higher with greater accumulations of snow. The estimated effects of weather conditions on physical activity were closer to the null in analyses stratified by season. Month, nevertheless, remained an important determinant of number of physical activity sessions engaged in.

In analyses stratified by month (data not shown), increased temperature was associated with increases in number of physical activity sessions reported in April and October only. Similarly, numbers of physical activity sessions engaged in were lower on days with rainfall in May, October, and November, but not in other months. However, the estimated effects of snowfall and snow accumulation for each winter month were congruent with the winter-specific estimates presented in Table 2.

Seasonal Differences in Organized Community Physical Activity

Consistent with the results for moderate or vigorous physical activities, involvement in organized community physical activity varied according to seasons (Fig. 2). Relative to winter, the mean number of organized physical activity was 6%, 9%, and 2% higher in spring, summer, and fall, respectively (Table 3). As for general physical activity, participation in organized community physical activities declined during adolescence (−16.3% per year, 95% CI = −16.7% to −15.9%). Girls also engaged in an average of 17.0% (95% CI = −18.0% to −15.9%) less organized community physical activities than boys.

None of the interaction terms tested suggested that the effects of weather conditions differed by sex or age (data not shown).
indoor activities including stationary cycling, aerobics, and weight-lifting are popular during cold months, whereas running, bicycling, gardening, and golfing are more popular in spring and summer (7, 35).

Marked declines in number of physical activity sessions engaged in were noted for the coldest months in each of the five study years. In addition to variation in weather conditions, the lower rates of physical activity may relate to decreased daylight during the winter. Over time, the winter declines in physical activity were followed by increases during warmer months. However, the increases were not sufficient to compensate for earlier decreases. This raises the hypothesis that the observed seasonal variation in the frequency of physical activity sessions engaged in is partly responsible for the decline in physical activity participation with age during adolescence. Through the 5 years of follow-up in this study, the average daily number of physical activity sessions decreased by nearly one third. Interventions aiming at maintaining physical activity involvement at increased levels during winter months could potentially slow physical activity decline over time. Maintenance of activity levels during winter could also help prevent seasonal weight gains (36).

Involvement in organized community physical activity was lower during winter and fall, and higher during spring and summer. It can therefore be estimated that the reduced

### DISCUSSION

Consistent with previous studies reporting that rain and cold are barriers to physical activity in the general population (12–14) and that adults and the elderly are less active on days with inclement weather (15, 16), we showed that adolescents were less physically active on rainy or snowy days. The effect of specific weather conditions was more important during specific periods of the year. For example, the link between physical activity and temperature was significant only in April and October. This likely pertains to the desire for many individuals to take advantage of the first and the last days of warm weather of the year.

The results suggest that daily fluctuations in weather are less important than the effect of month. This may be because spontaneous and unplanned physical activities are the most affected by weather conditions. Recent findings suggest these types of physical activities are now much less popular among adolescents than structured activities, which are planned and scheduled ahead of time (and thus less likely to be canceled because of inclement weather) (33, 34). Moreover, the relatively small influence of weather condition on physical activity may relate to participation in season-specific activities that can be engaged in over the range of usual weather for the season. The popularity of specific activities changes with season (35). Among adults, indoor activities including stationary cycling, aerobics, and weight-lifting are popular during cold months, whereas running, bicycling, gardening, and golfing are more popular in spring and summer (7, 35).

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Involvement in organized community physical activity was lower during winter and fall, and higher during spring and summer. It can therefore be estimated that the reduced
participation in organized physical activities during the colder periods influences the number of physical activity sessions engaged in. Interventions to increase adolescents’ physical activity participation during colder months could thus consider promoting and increasing availability of community-based physical activities. A study conducted in a Canadian city showed that the number of publicly provided spaces for outdoor recreation (e.g., baseball and soccer fields) were 15 times more prevalent than indoor facilities (e.g., indoor ice rinks, gymnasiums) (37). However, other studies found that children were considerably more active when outdoors than indoors (38, 39). We are therefore not advocating that indoor physical activities be preferred to outdoor activities, simply that efforts be made to ensure that a variety of activities, including indoor physical activities, be available during winter.

Limitations of this study include a low response proportion at baseline. This was related to the need for blood draws for genetic analysis and to a province-wide labor dispute that resulted in some teachers refusing to distribute and collect consent forms. There were no objective measures of physical activity and our instrument only measured frequency of participation in physical activities. However, repeated use of a physical activity checklist, as in this study, provides a valid estimation of the level of moderate and vigorous physical activity participation (40). The use of questionnaires also enabled investigation of several types of physical activity, and not solely activities involving walking or running. We could not determine if activity sessions took place indoors or outdoors. The importance, relative to health outcomes, is nevertheless more related to levels of physical activity than to the area where activities are practiced. Finally, there were no data collection events during July and August. Some of our data nonetheless allowed us to evaluate the effect of seasons year round.

In summary, adolescents in this study participated in fewer physical activities on days when it rained or snowed, and during colder than warmer months. Although physical activity increased in spring and summer, the increase was always less than the decrease that occurred during the preceding winter. This may contribute to explaining why physical activity levels decline during adolescence. Our results call for efforts to increase opportunities for physical activity during winter months and to promote physical activities that can be engaged in on rainy and snowy days.

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<table>
<thead>
<tr>
<th>Season</th>
<th>Difference*</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>(reference)</td>
<td></td>
</tr>
<tr>
<td>Spring</td>
<td>6% higher</td>
<td>4% to 8%</td>
</tr>
<tr>
<td>Summer</td>
<td>9% higher</td>
<td>7% to 11%</td>
</tr>
<tr>
<td>Fall</td>
<td>2% higher</td>
<td>0% to 4%</td>
</tr>
</tbody>
</table>

CI = confidence interval.
*Percentage difference derived from Poisson regression rate ratio.
1Adjusted for school, age, and sex.
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