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Seasonal variations in physical activity among Norwegian elementary school children in Arctic regions

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ABSTRACT
The aim of this study was to measure seasonal variations in physical activity (PA) during Polar Nights (PN) and Polar Days (PD) among elementary school children in the Arctic regions of Norway. One hundred and seventy-eight schoolchildren from 1st, 3rd, 5th and 7th grade participated in the study. Physical activity was measured for seven consecutive days with an ActiGraph GT3X-BT accelerometer and is expressed as total PA incounts per minute (cpm) and moderate-to-vigorous activity (MVPA) (min·day^{-1}). During PN, 51% of boys and 33% of girls met the PA recommendations, whereas 36% of boys and 34% of girls met the recommendations during PD. Time spent doing MVPA did not differ between the two seasons (all $p \geq 0.073$). Overall, the children accumulated 613 ±154 cpm during PN, which was lower than during PD 704 ± 269 cpm, $p < 0.001$). A larger proportion of boys than girls met the PA recommendations during PN compared with PD. Our findings did not show any clear seasonal variation for MVPA or total PA among children,except for some differences within sexes in different grades. This study indicates that interventions aimed at increasing PA should be implemented throughout the year in the Arctic regions. .

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Accelerometer; Seasonal variation; Schoolchildren; Arctic region; Polar Night; Polar Day

Background

Physical activity (PA) during childhood has a positive effect on cardiometabolic risk and other health markers [1,2], which tracks into adulthood [3]. It is recommended by the World Health Organisation that children spend an average of ≥60 min·day-1 in moderate-to-vigorous physical activity (MVPA) [1].

Despite the immediate and long-term health benefits of PA in childhood, many children fail to meet these recommendations in Europe [4]. Several interventions in Norway have been implemented to promote PA in children [5,6]. Despite these efforts, PA in Norwegian children has been stable over the years [7,8]. In a recent meta-analysis of harmonised accelerometry measured PA in European children, only 29% of children and adolescents were determined sufficiently active [9]. Moreover, PA decreases with increasing age, where those aged 4 – 5 years are most active and a pronounced decline in PA level is observed from 6 to 9 years, falling even further into adolescence [9]. In all ages, girls are less active than boys, where boys spend on average ~10 minutes more doing MVPA per day than girls [9]. These findings were mirrored in the latest Norwegian national survey on school children [8]; 87% of six-year-old girls and 94% of the boys were sufficiently active, where a pronounced decline to 64% and 81% were observed for nine-year old girls and boys, respectively. The corresponding numbers among Norwegian 15-year-olds were 40% and 51% for girls and boys, respectively [8].

Seasonality (i.e. winter and summer) has received little attention as a potential environmental determinant of PA for children and youth in the Arctic region. In accordance with different seasons, weather, temperature and daylight hours may influence children's PA level [10]; however, these observations are inconsistent [11]. In the northern hemisphere, we may expect children and adolescents to perform larger amounts of PA during Polar Days (PD) than during Polar Nights (PN). Shorter daylight length and lower temperatures, typical of fall and winter months, is associated with lower activity in children [12]. A main characteristic of regions above the Arctic Circle is a large seasonal variation in daylight length, which affects the weather through

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variation in temperature, precipitation and windspeed [13]. During PN (mid-November to mid-January), the sun does not rise above the horizon, whereas during PD (mid-May to mid-July) the sun does not set, resulting in 24 hours of daylight.

To our knowledge, no study has compared PA patterns in elementary school children during the PN and PD periods in the Arctic region of Norway The aim of this study was to describe PA across PN compared to the PD among elementary school children in the Arctic region of Norway. We hypothesised that children's PA level is larger in the summer than in the winter in the Arctic region of Norway.

Methods

This longitudinal cohort study includes children living above the Arctic Circle in Tromsø, Northern Norway. In collaboration with the school management in the municipality, two elementary schools located in the city centre were selected to participate in the study. We invited 283 children from 1st (6 years old), 3rd (8 years old), 5th. (10 years old) and 7th (12 years old) grade to participate. Of these, 178 children (94 girls and 84 boys) provided valid accelerometry data and are included in our analysis (Table 1). Data collection was carried out in December 2017 to represent PN, and in June 2018 to represent PD. The schools were chosen based on their location in Tromsø city, in two different local environments. As the sample in our study included younger age children, we chose not to include any questionnaires on ethnicity and socioeconomic background, as this can be difficult to answer or be perceived as discrimination by the children.

Participation was voluntary for the schoolchildren and required written approval from the parents/legal guardians. The parents received written information about the study in advance through the schoolteachers. The Norwegian Center for Research Data approved the storage of personal data (reference number: 56212) and the study was carried out in accordance with the Declaration of Helsinki.

Procedure and analysis

The accelerometer's functions and usage were explained to the children and fitted to each child with an elastic band around their right hip. The children were told to wear the monitor during all waking hours for seven consecutive days, except for water-based activities (*e.g.* swimming, showering) as it is not waterproof. The children were attending school during both periods and the data included five weekdays and two weekend days. PA was measured by an ActiGraph wGT3X-BT (ActiGraph, LLC, Pensacola, Florida, USA) accelerometer. The accelerometer was initialised, and data were downloaded using the software program ActiLife v.6.13.3 (ActiGraph, LLC, Pensacola, Florida, USA). To prevent potential accelerometry reactivity (abnormally high activity) in the children during the first hours after receiving the accelerometer, the device was set to start recording at 06:00 the day after the monitors were handed out. Night activity data between 24:00 and 06:00 were excluded. The raw acceleration was reduced to 10-second epoch intervals in the ActiLife Software. Blocks of ≥ 20 minutes without any registered activity (0 counts per minute (cpm)) were considered as non-wear time and excluded from further analyses, which was excluded manually in Excel spreadsheets (Microsoft Corporation, Redmond, WA, USA). Inclusion criteria for data analysis was minimum two days wear time with at least eight hours of recorded data each day. The PA outputs were extracted from the ActiLife Software. Total PA level was expressed as cpm and included all acceleration the monitor had been exposed to, divided by wear time per day. We defined MVPA as all activity > 2000 cpm [8,11].

Table 1. Seasonal variations in participant characteristics by sex and age group (N = 178).

N = 178	1st grade		3rd grade		5th grade		7th grade	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
Total (n)	28	27	20	15	26	21	20	21
Age (y)	5.9 ± 0.3		7.9 ± 0.2		9.9 ± 0.3		11.9 ± 0.3	
Physical Activity Polar Night								
Total PA (cpm)	655 ± 77	727 ± 112	633 ± 112	673 ± 205	524 ± 112	566 ± 123	543 ± 150	598 ± 222
MVPA (min-day^{-1})	55 ± 15	68 ± 23**	58 ± 18	70 ± 29	45 ± 22	56 ± 22	50 ± 19	62 ± 30
Wear Time (min-day^{-1})	606 ± 57*	578 ± 112*	638 ± 48*	602 ± 71	552 ± 139	583 ± 130*	617 ± 70*	631 ± 92*
Physical Activity Polar Day								
Total PA (cpm)	792 ± 188**	763 ± 169	823 ± 207*	906 ± 240	677 ± 384	633 ± 210	545 ± 187	553 ± 212
MVPA (min-day^{-1})	47 ± 21	42 ± 25	45 ± 21	56 ± 33	71 ± 34*	59 ± 30	47 ± 25	51 ± 27
Wear Time (min-day^{-1})	454 ± 130	420 ± 188	518 ± 164	470 ± 197	530 ± 131	436 ± 180	420 ± 174	481 ± 193

Data are shown as mean ± standard deviation PA, physical activity; MVPA, moderate-to-vigorous physical activity, cpm, counts per minutes.
*$p < 0.005$ ** $p < 0.001$ significant between seasons.

Seasons and weather

For seven consecutive days when the data were collected in December 2017 and in June 2018, weather data were obtained from the Norwegian Meteorological Institute [14]. During PN, an average temperature (Mean ± Standard deviation (SD)) of – 1.6 ± 3.5 degrees Celsius and zero hours of sunshine was recorded. Moreover, the average strongest mean wind was 12.8 ± 5.4 m·s^{-1} and the amount of precipitation was 3.1 ± 4.9 mm·day^{-1}. During PD, the average temperature was 6.5 ± 4.1 degrees Celsius, and the average hours of sun was 5.3 ± 3.5 hours. The strongest mean wind was on average 12.1 ± 3.2 m·s^{-1}, and the amount of precipitation was 3.2 ± 4.0 mm·day^{-1}.

Statistical analyses

Statistical analyses were performed using the IBM Statistical Package for Social Sciences, version 25 (IBM SPSS Statistics, Armonk, NY, USA). Independent t-tests were used to assess differences in PA levels between sexes. Paired t-tests were used to assess differences in PA level and total wear time between seasons. Chi-square (McNeamar) analysis was used to assess the percentage of children meeting the recommended PA guidelines between seasons and to calculate the odds ratio between sexes. Univariate analyses of variance (ANOVA) were used to find differences in PA levels between grades and sexes, with Bonferroni-corrected post-hoc tests when observing a main difference between grades. Statistical significance was set to $p < 0.05$. Data are shown as mean ± SD or as percentage (%).

Results

Average accelerometry wear time per valid days was higher during PN (9.9 ± 1.7hours-day^{-1}) compared with PD (7.7 ± 2.8 hours-day-$^{1)}$) (p < 0.001).

Seasonal, grade, and sex differences in MVPA

Boys were twice as likely as girls to meet PA recommendations during PN (boys: 51%, girls 33%, OR 2.13, $p = 0.014$), while no difference was found during PD (boys: 36%, girls: 34%, OR 1.07, $p = 0.82$, Figure 1). When stratified by grade, we observed no differences in children meeting the PA recommendations (Figure 1).

Time spent doing MVPA (min·day^{-1}) did not differ between PN and PD for any of the grades except for boys in 1st grade and girls in 5th grade (both $p \leq 0.005$) (Table 1). Boys in 1st grade spent 26 ± 29 more minutes per day doing MVPA during PN compared with PD ($p < 0.001$), while girls in 5th grade spent 26 ± 36 more minutes per day doing MVPA during PD compared with PN ($p = 0.005$). The only difference between sexes for time spent doing MVPA was in 1st grade during PN, where boys spent 13 ± 5 more minutes per day doing MVPA than girls ($p = 0.002$).

During PD, there were only differences in MVPA between girls in 1st and 5th grade, and in boys in 3rd and 5th grade (all $p < 0.05$). Girls in 5th grade spent 24 ± 7 more minutes per day doing MVPA than girls in 1st grade, and 26 ± 8 more minutes per day doing MVPA than girls in 3rd grade (all $p < 0.005$).

Seasonal differences in MVPA during weekends and weekdays

Overall, there were no differences in MVPA in weekdays between PD and PN (Figure 3). Boys and girls in 7th grade accumulated 33 ± 20 ($p < 0.05$) and 22 ± 12 more minutes per day in MVPA ($p < 0.001$), respectively, during PN weekend days compared with PD weekend days (Figure 3). Children in all grades accumulated more time in MVPA during weekdays compared with weekend days during PN (all $p < 0.05$) and PD (p < 0.001) (Table 2).

Seasonal, grade and sex differences in mean total PA (cpm)

Overall, the children accumulated more total PA during PN (704 ± 269 cpm) than PD (613 ± 15 cpm) ($p < 0.001$). When stratified by grade and sex, only girls in 1st and 3rd grade showed seasonal differences (Table 1 and Figure 2); during PD, girls in 1st grade accumulated 137 ± 111 more cpm ($p < 0.001$), and girls in 3rd grade accumulated 190 ± 95 more cpm ($p < 0.001$) compared with PN. Differences between sexes were only found during PN, where boys accumulated 56 ± 294 more cpm than girls ($p < 0.05$).

When stratified by grade, sex differences were only observed among children in 1st grade.

Between grades, girls in 1st and 3rd grades had significant higher total PA during PN than girls in 5th and 7th grade (Table 1) ($p < 0.05$). This difference was not found during PD ($p \geq 0.22$). Boys in 1st grade accumulated higher cpm in both PN and PD compared with boys in 5th and 7th grade (Table 1) ($p < 0.05$).

Discussion

In this longitudinal cohort study, the proportion of boys meeting the PA recommendations was larger during PN compared with PD, but there was no seasonal effect for

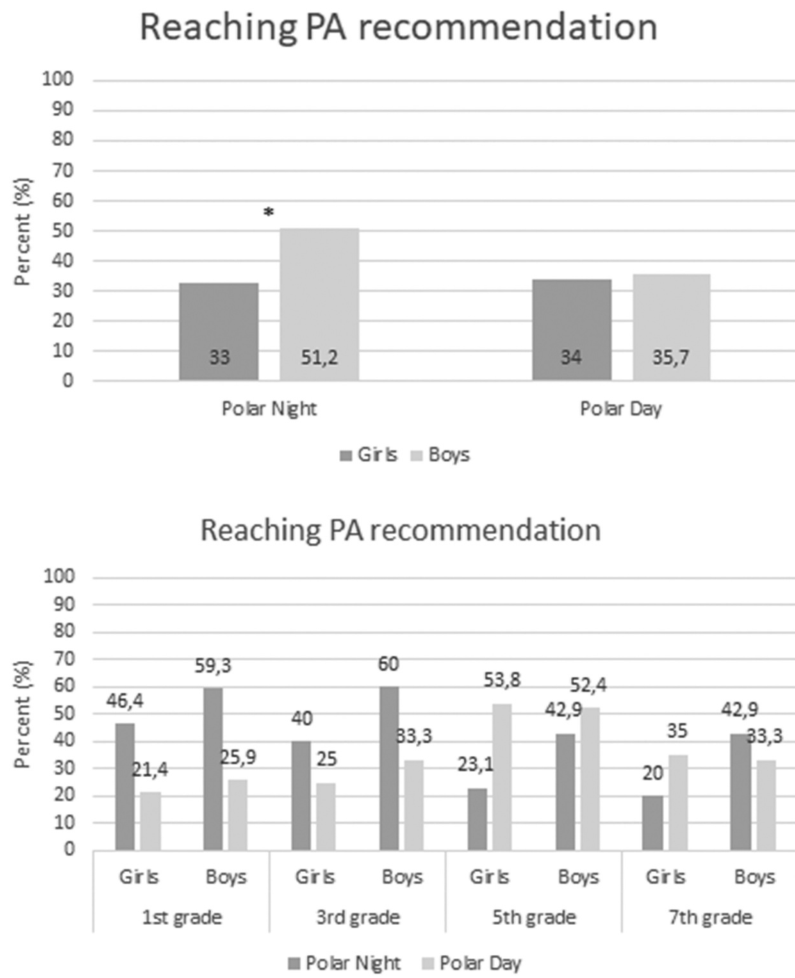

Figure 1. Propotion of children who met the PA recommendations by grade, sex and season (bottom) and sex and season (top). *$p < 0.05$.

girls in meeting PA recommendations. Consequently, we could not confirm our hypothesis that the children's PA level is higher during PDcompared with PN. Moreover, boys were more physically active than girls during PN, while this was not observed during PD.

Achievement of recommended PA and seasonal, age, and sex differences in MVPA

The proportion of children in our study who met the PA recommendations was smaller compared with a national representative cohort [7]. However, our results are similar to a study of indigenous Saami children in the Arctic area of Norway [15]. This may indicate that the influence of Arctic regions results in lower PA compared with southerly regions in Norway and may be explained by climate and temperature, as Arctic regions are colder in both winter and summer months. Colder temperatures may limit the children´s opportunities to be outside [10,16,17]. At the same time, PA levels in our study were similar to a large European study of accelerometry measured PA levels in children [9]. These observations may indicate that children in Norway are more active than the rest of Europe [7,9], while at the same time those in Arctic regions in Norway perform lower amounts of PA being consistent with European children [9].

Consequently, Norwegian public health authorities should prioritise creating opportunities for children to be physically active, both during school hours and leisure time. This may involve other initiatives in Arctic regions than other more southerly regions. As playground parks are found to increase PA in children [18,19], such initiatives in Arctic regions can include creating winter playgrounds during PN, such as snowslide parks, ice skating fields and clearing snow to facilitate free movement for younger children. Summer initiatives may not differ from common PA initiatives from policymakers, which can include educating

Table 2. Seasonal variations in physical activityin weekdays and weekend days by sex and age group (N = 178).

	1st grade		3rd grade		5th grade		7th grade	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
Physical Activity weekdays PN								
Mean PA (cpm)	679 ± 79$^{\neq}$	761 ± 103$^{\neq\neq}$	660 ± 101$^{\neq}$	712 ± 223 $^{\neq}$	559 ± 102	587 ± 133	542 ± 162	613 ± 235
MVPA (min-day^{-1})	61 ± 18$^{\neq\neq}$	77 ± 24$^{\neq\neq}$	66 ± 17$^{\neq\neq}$	81 ± 33$^{\neq\neq}$	51 ± 22$^{\neq\neq}$	63 ± 26$^{\neq}$	56 ± 22$^{\neq\neq}$	69 ± 32$^{\neq}$
Physical Activity weekdays PD								
Mean PA (cpm)	845 ± 249$^{\neq}$**	779 ± 167$^{\neq}$	776 ± 270	946 ± 292$^{\neq}$*	734 ± 394$^{\neq}$*	638 ± 229	641 ± 208*	585 ± 241$^{\neq}$
MVPA (min-day^{-1})	67 ± 23$^{\neq}$	73 ± 33 $^{\neq\neq}$	82 ± 28$^{\neq\neq}$	99 ± 37 $^{\neq}$	68 ± 41$^{\neq\neq}$	64 ± 33 $^{\neq\neq}$	48 ± 20$^{\neq\neq}$	58 ± 20$^{\neq\neq}$
Physical Activity weekend Days PN								
Mean PA (cpm)	581 ± 130	614 ± 221	551 ± 205	543 ± 253	502 ± 194	505 ± 191	481 ± 180	519 ± 306
MVPA (min-day^{-1})	40 ± 20	45 ± 31	39 ± 29	44 ± 29	29 ± 32	40 ± 27	35 ± 25**	47 ± 39*
Physical Activity weekend days PD								
Mean PA (cpm)	627 ± 394	591 ± 268	616 ± 400	657 ± 354	599 ± 433	619 ± 589	422 ± 270	395 ± 283
MVPA (min-day^{-1})	51 ± 36	51 ± 31	44 ± 19	46 ± 41	37 ± 33	31 ± 323	15 ± 18	16 ± 16

Data are shown as mean ± standard deviation.
PA, physical activity; MVPA, moderate-to-vigorous physical activity *$p < 0.005$ **$p < 0.001$ significant between seasons.
$^{\neq}p < 0.005$ $^{\neq\neq}p < 0.001$ significant between week vs weekend in seasons.

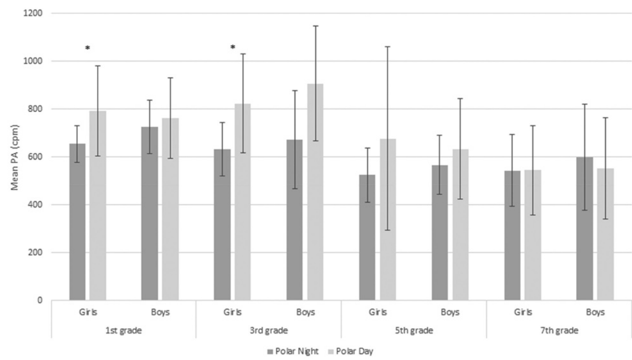

Figure 2. Mean PA (cpm) with error bars as SD stratified by grade, sex and season $*p < 0.05$ between PN and PD.

caretaker staff [20,21] and parents [22,23] on PA promotion, creating playgrounds [18,19] and providing safe travel for bicycling [24,25].

Our study showed small seasonal differences in time spent doing MVPA, except for boys in 1st grade, who accumulated 26 more minutes of MVPA during PN, and girls in 5th grade who accumulated 26 more minutes of MVPA during PD. One previous study on seasonal variation among Norwegian children's MVPA levels has shown higher odds of meeting the recommended MVPA level in the summer/spring compared with the winter [11]. Moreover, boys were twice as likely to meet the recommendations as girls during PN, but the proportion of boys meeting recommendations dropped in the summer; thus, we observed no sex difference in meeting recommendations during the summer.

When we combined the results of lower grades (1st and 3rd grade) and higher grades (5th and 7th grade), children from the lower grades spent an average of 10 more minutes doing MVPA compared with the children in the higher grades during PN. During PD, the results were the inverse, with the older children spending 10 more minutes doing MVPA than the younger children. Thus, we could only observe a consistent decline in PA by increasing age [8,9] during PN. This can be explained by daylight, as children are more active in summer

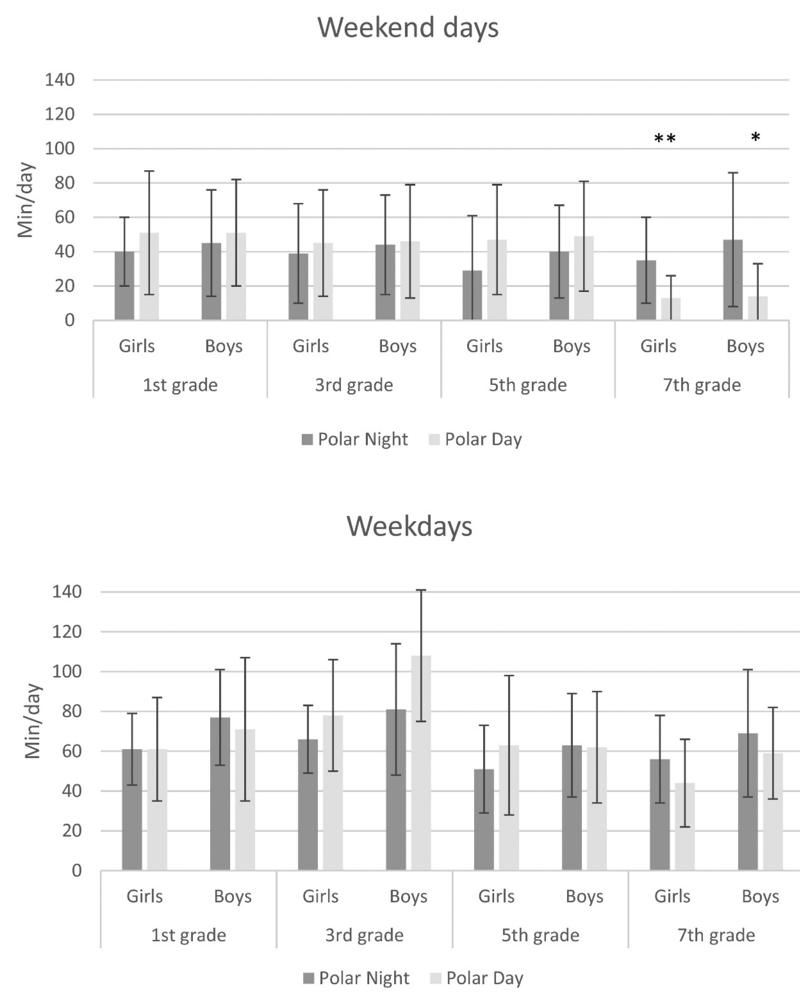

Figure 3. Time spent in MVPA, moderat-to-vigorous physical activity. Mean (min-day^{-1}) with error bars as SD during weekdays (bottom) and weekend days (top) stratified by sex, grades between season. $*p < 0.05$; $**p < 0.001$.

months [26] and shorter daylight length results in lower PA [12]. Such effects may be more pronounced in older children in the Arctic region as they may perceive poor weather and cold temperatures as unenjoyable [10,17].

During both PN and PD, MVPA was higher throughout weekdays compared with weekend days. Our results are similar to findings in a multi-country analysis [27], where more MVPA was accumulated during school days. It is previously observed that children perform higher intensity PA outside than PA inside [28]. For example, the parents´ PA level is found to be associated with PA levels in their children [29,30]. Thus, educating parents on the importance of outdoor play for children may help parents to stimulate for increased MVPA during weekend days [22,23].

Seasonal, age, and sex differences in total PA

Only girls in 1st and 3rd grades accumulated more total PA (cpm) during PD than during PN, while no differences were observed among lower grade boys, and higher grades boys and girls. Our findings are partly consistent with a previous study that showed that daylight length affects children's PA levels [12], while we only observed this for girls. Other studies have shown that outdoor activity increases in the summer period, and it is also observed generally more activity during summer months than winter months [12,26,31]. As this was not observed in our study, it seems that those living in the Arctic regions of Norway are less affected by seasonal variations and cope well with the cold climate and long winter months. A previous large-scale study in Northern Norway found no differences in mental distress between seasons [32], which illustrates the population´s coping capabilities with the cold climate and long periods with no sun.

Weather considerations

During our data collection in June (PD), it was a rainier period compared with the average June weather over the last four years (3.2 vs 2.1 mm·day^{-1}). Moreover, the average temperature was lower than the average June (6.5 vs 10.1 degrees Celsius). Although there is daylight for 24 hours during PD, the average amount of sunshine was only 5.3 hours a day during our PD data collection. Previous studies have shown lower activity among children during rainfall [12] and other studies indicate that daylight and temperature may increase PA [31,33]. Thus, it is likely that weather conditions affected the children's PA in our study, which may partly explain the lower activity level during PD. The weather during the PN data collection was more similar to the average temperature for December (−1.6 vs −0.8 degrees Celsius) and precipitation (3.1 vs 3.3 mm·day^{-1}) during the last four years.

Because of the weather conditions during our PD data collection, the temperature difference between the two seasons was smaller than expected, which may partly explain the low variation in PA. However, it is difficult to conclude whether weather conditions or differences in daylight between the two seasons completely account for the low seasonal variation in the children's PA. As mentioned above, it may simply be that temperature and weather do not influence children's PA level above the Arctic Circle, as there are opportunities for activities in the snow, such as skiing and sledding, which may increase PA levels. Such activity is not so accessible in more southern parts of Europe or elsewhere, due to low amounts of snow. Additionally, many children are active in organised leisure time activities [34] and many of these activities are indoors during winter and are therefore not influenced by weather conditions.

Strengths and limitations

The main strength of this study is the device used to measure PA levels. Self-reported PA in children relies on proxy reports from parents, which are prone to recall bias [35]. Consequently, our accelerometry measured PA may reflect the actual PA levels to a larger extent than self-report measures. This allows for firmer interpretations of the influences on children's PA levels in Arctic regions. Another strength is the large variation in age, which allowed us to assess PA levels across ages in elementary school.

Our study has some limitations that should be addressed. First, accelerometry measured PA underestimates activities like cycling due to lack of body movement (here, movements in the hip), as well as water-based activities, as it is not waterproof and children were instructed to take it off [36]. However, cycling activity is generally low in winter months due to snow and ice, and swimming is usually performed indoors in the Arctic. Consequently, accelerometry assessment has advantages over other methods. Second, mean wear time was generally higher during PN compared with PD, which may have affected our results. Longer wear time may affect total cpm, while MVPA is likely similar across wear time lengths due to the high cpm cut-off [37]. Third, the small sample size in our study might have affected our results. For example, other studies have observed lower PA with increasing age [38] while we only observed this during PN. Fourth, although inconsistent [39,40], socioeconomic status of children´s parents are reported in some studies to influence children's PA level [41,42]. The cultures in different ethnicity groups are also reported to influence PA levels in children [39,41]. Consequently, unavailable data on socioeconomic status and ethnicity prevent us from assessing how these factors influence the results in our study. Finally, the one-week data collection in the two seasons, respectively, may not be representative for the average weather conditions.

Conclusion

The proportion of boys meeting the PA recommendations was higher during PN compared with PD, while no seasonal effect on meeting PA recommendations was observed for girls. However, our findings did not show any clear seasonal variation for MVPA or total PA among children in the Arctic region of Norway, except for some differences within sexes in different grades. This study indicates that interventions aimed at increasing PA should be implemented throughout the year in the Arctic region, both during school hours and leisure time.

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