



## Boys, older children, and highly active children benefit most from the preschool arena regarding moderate-to-vigorous physical activity: A cross-sectional study of Norwegian preschoolers

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### ABSTRACT

The preschool environment exerts an important influence on children's behaviour, including physical activity (PA). However, information is lacking regarding where and when most of children's PA is undertaken. This study aimed to describe PA and sedentary time (SED) during preschool hours and time out-of-care, and on weekdays and weekend days, and to investigate differences in PA patterns according to sex, age, and MVPA levels. From September 2015 to June 2016, we measured PA levels of 1109 children (age range, 2.7–6.5 years; mean age 4.7 years; boys, 52%) using ActiGraph GT3X+ accelerometers for up to 14 consecutive days. We applied a linear mixed model to analyse associations and interactions between total PA (counts per minute [cpm]), light PA (LPA), moderate-to-vigorous PA (MVPA), SED, sex, age, and overall MVPA regardless of setting, during preschool hours versus time out-of-care, and on weekdays versus weekend days. Children undertook more PA and less SED on weekdays compared to weekend days ( $p < 0.01$ ). For boys, MVPA levels were higher during preschool hours than during time out-of-care ( $p < 0.05$ ). Differences in total PA and MVPA between preschool hours versus time out-of-care, and between weekdays and weekend days, were greater in boys, older children, and highly active children than in girls, younger children, and children with lower overall MVPA levels ( $p < 0.01$ ). The preschool arena is important for children's PA. Concerning MVPA, this study showed that boys, older children, and highly active children benefit more from this environment compared to girls, younger preschoolers, and children with lower MVPA levels.

### 1. Introduction

Physical activity (PA) during the preschool years has been favourably associated with children's health and development, in terms of adiposity, cardiometabolic indicators, psychosocial health, and development of fundamental motor skills (Timmons et al., 2012). Moreover, especially moderate-to-vigorous PA (MVPA) has been associated with reduced metabolic risk in children (Janssen and Leblanc, 2010; Poitras et al., 2016; Ekelund et al., 2012; Andersen et al., 2006), and is important in preventing childhood obesity (Lambourne and Donnelly,

2011). However, low levels of MVPA have been reported in preschool-aged children internationally (Bornstein et al., 2011; Reilly, 2010; Hnatiuk et al., 2014).

Although parents provide most of young children's care, children under the age of 6 also spend large amounts of time in preschools. In Norway, 97% children aged 3–5 years attend preschools (Statistics Norway, 2017) (hereafter defined as preschoolers), which is an even higher percentage than the European mean attendance rate (90%) (European Commission, 2009). Additionally, Norwegian preschoolers spend an average of 33 h per week in preschool (The Norwegian

**Abbreviations:** PA, physical activity; TPA, total physical activity; SED, Sedentary behaviour; LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; Min, minutes; cpm, counts per minute; SD, standard deviation; SES, Socioeconomic status; CI, confidence interval; ICC, intraclass correlation

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Directorate for Education and Training, 2017). Consequently, this environment potentially exerts a significant influence on children's behaviour, including PA.

Objective monitoring of PA in preschoolers has increased in recent years. However, most previous studies have only reported PA during preschool hours or total PA regardless of setting, and have not considered the potential individual differential effect of time and place on children's PA. Knowledge of where and when preschoolers are physically active is essential to initiate interventions aimed to increase PA in young children, and to make specific recommendations on how preschoolers should attain guideline amounts of PA (in Norway: 60 min MVPA/day regardless of the child's age (Tetens, 2012)). Nevertheless, some studies have shown that PA in preschoolers differs over the course of the day and the week (Hesketh et al., 2015; Van Cauwenberghe et al., 2012; O'Dwyer et al., 2014; Hesketh et al., 2014; Moller et al., 2017; Berglund and Tynelius, 2017; O'Neill et al., 2016). However, these studies are limited due to small sample sizes (size range,  $n = 188\text{--}341$ ) (Hesketh et al., 2015; O'Dwyer et al., 2014; Moller et al., 2017; O'Neill et al., 2016) and, more importantly, results are conflicting regarding where and when children are most active. Some studies have reported that children are least active during preschool hours (Van Cauwenberghe et al., 2012; O'Dwyer et al., 2014; O'Neill et al., 2016), while other studies have found that children undertook more total PA and MVPA during preschool hours compared to time out-of-care (Hesketh et al., 2015; Moller et al., 2017; Berglund and Tynelius, 2017).

A recent review by Tonge et al. concluded that differences in PA exist between boys and girls and across age groups within the preschool population (Tonge et al., 2016), in favour of boys and older children. However, there is limited evidence on whether the observed sex- and age differences in PA are present to a similar degree across settings, or whether such differences depend on overall PA levels.

This study aimed to describe the distribution of PA and sedentary time (SED), in particular MVPA, during preschool hours vs. time out-of-care, and on weekdays vs. weekend days, in a large sample of Norwegian preschoolers, and to investigate differences in PA patterns across sex, age, and overall MVPA levels.

## 2. Methods

### 2.1. Study design and recruitment of participants

The Sogn og Fjordane Preschool Physical Activity Study was a population-based cross-sectional study conducted in the rural county of Sogn og Fjordane in western Norway, between September 2015 and June 2016. Out of 26 municipalities in the county, 15 were invited to participate. Municipalities were strategically selected based on the population average parental education level, population size, and geographical location, average number of children per preschool, and average number of children per preschool teacher. One municipality chose not to take part in the study. In total, 68 of 74 invited preschools participated in the study. All 1925 children born in 2010–2012 within the participating preschools were invited, of whom parents received oral and written information about the study. Parents of 1308 children provided written consent prior to testing (response rate; 68%). We explained procedures to the participating children according to their level of understanding. The Norwegian Centre for Research Data (NSD) approved the study (reference number: 39061).

### 2.2. Procedures

PA was measured using the ActiGraph GT3X+ accelerometer (ActiGraph, LLC, Pensacola, Florida, USA). Accelerometers were mounted on a participating child's right hip, and children were instructed to wear the monitor at all times for 14 consecutive days, except during water-based activities and while sleeping (at night). Accelerometers were initialized with a sampling rate of 30 Hz and

analysed in 10-s epochs using KineSoft software (KineSoft version 3.3.80, Loughborough, UK). Periods of  $\geq 20$  min of zero counts were defined as non-wear time (Esliger et al., 2005). "Preschool hours" were based on average delivery/pick-up time for the current sample (time-stamped data), defined as between 08:30 am and 15:29 pm on weekdays ( $SD \pm 0:30$  h for both time points). All leisure time, including "morning" (06:00–08:29 h) and "afternoon" (15:30–23:59 h) on weekdays, was defined as "time out-of-care". Our criterion for a valid day was  $\geq 480$  min of wear time accumulated between 06:00 and 24:00 h (both weekdays and weekend days). All participants included in the analysis for the present study had to have  $\geq 30$  min wear time in the "morning",  $\geq 270$  min wear time during "preschool hours", and  $\geq 180$  min in the "afternoon" on weekdays. We included all children who provided  $\geq 3$  weekdays and  $\geq 1$  weekend day of valid data in the analysis. Outcomes were total PA (TPA) (counts per min [cpm]) and intensity-specific PA, reported as SED ( $\leq 100$  cpm), light-intensity PA (LPA) (101–2295 cpm), and MVPA (min/day) ( $\geq 2296$  cpm) (Evenson et al., 2008).

Children's sex, age, and parental socioeconomic status (SES, based on the highest education level and the highest yearly income of mother or father) were assessed using a questionnaire that had been completed by the child's mother and/or father. We assessed children's body weight and height during preschool hours. Body weight was measured to the nearest 0.1 kg using an electronic scale (Seca 899, SECA GmbH, Hamburg, Germany), and height was measured to the nearest 0.1 cm with a portable stadiometer (Seca 217, SECA GmbH, Hamburg, Germany). Body mass index (BMI,  $\text{kg}/\text{m}^2$ ) was calculated, and children were classified as normal weight, overweight, or obese, based on criteria proposed by Cole et al. (Cole et al., 2000). Seasons were categorized as autumn (September–December), winter (January–March), and spring/summer (April–June).

### 2.3. Statistical analysis

Children's characteristics, PA, and SED were reported as frequencies, means, and standard deviations (SD), except for the number of valid days of accelerometer data, which was reported as median. To account for the clustering of observations within preschools, all analyses for continuous outcomes were performed using a three-level linear mixed model that included random intercepts for children and preschools (i.e., observations were clustered within children and children were clustered within preschools). For categorical outcomes, we used generalized estimating equations defining preschools as the cluster variable using an exchangeable correlation structure.

We performed two types of main analyses. First, we compared the amount of PA during preschool hours vs. time-out of care and on weekdays vs. weekend days. Second, we analysed sex, age, and overall MVPA as moderators of PA across settings/time of week by analysing interactions for setting/time of week according to those characteristics (e.g. sex\*setting, age\*setting, overall MVPA\*setting, etc.), and we reported the associated p-values. Main effect estimates ( $\beta$  coefficients) and 95% confidence intervals (CI) were calculated separately for preschool hours, time out-of-care, weekdays, and weekend days. Interaction analysis was performed in two steps across both comparisons (preschool hours vs. time-out of care, weekdays vs. weekend days). First, we tested the interactions of sex\*setting/age\*setting (in the same model) and sex\*time of week/age\*time of week (in the same model), and second, we included the interaction of overall MVPA\*setting/MVPA\*time of week to the above-mentioned models.

PA was the outcome in all models, and all models were controlled for parental SES, accelerometer wear time (except for descriptive mean values), season, and BMI. Intraclass correlations (ICC) was calculated as the variance in PA explained by preschool divided by total variance. All analyses were performed using IBM SPSS v. 24 (IBM SPSS Statistics for Windows, Armonk, NY; IBM Corp., USA).  $p < 0.05$  indicated statistically significant findings.

**Table 1**  
Children's characteristics.

	Total sample N = 1109	Boys n = 572	Girls n = 537
Age (years) (mean ± SD)	4.7 (0.9)	4.8 (0.9)	4.7 (0.9)
Ethnicity of child			
Born in Norway	978 (97%)	503 (97%)	475 (97%)
Mother born in Norway	891 (89%)	461 (89%)	430 (88%)
Father born in Norway	884 (88%)	460 (89%)	424 (87%)
Age-specific weight status			
Normal	883 (81%)	470 (84%)	413 (78%)
Overweight	173 (16%)	76 (14%)	97 (18%)
Obese	28 (3%)	9 (2%)	19 (4%)
Parental education level <sup>a</sup>			
Upper secondary school	104 (10%)	52 (10%)	52 (10%)
University < 4 years	441 (42%)	223 (41%)	218 (43%)
University ≥ 4 years	504 (48%)	262 (49%)	242 (47%)
Parental income level <sup>a</sup>			
< 32,500 EUR	56 (6%)	28 (5%)	28 (6%)
32,500–62,000 EUR	619 (62%)	328 (64%)	291 (60%)
> 62,000 EUR	325 (32%)	161 (31%)	164 (34%)

All values are n (%) unless stated otherwise; SD, Standard deviation; weight status defined according to Cole et al., 2000. The study was conducted in Sogn og Fjordane county, Norway, between September 2015 and June 2016.

<sup>a</sup> Parental education level and yearly income: highest level for mother or father was used.

### 3. Results

#### 3.1. Sample description

Of 1308 study participants, 1109 (85%) children provided valid accelerometer data and were included in the analyses (Table 1). The children had a median 13 valid days of PA registration in total (4–7 days, 4%; 8–11 days, 28%; and > 12 days, 68%); a median of 9 weekdays (3–4 days, 2%; 5–7 days, 15%; and > 8 days, 83%), and 3 weekend days (1 day, 8%; 2 days, 18%; and > 3 days, 74%), respectively. Compared to children who provided valid accelerometer data, those who did not (n = 199) were slightly younger than the included children (p < 0.01), and had parents with lower educational levels (p < 0.05). The included and excluded children did not differ regarding BMI, sex, or parental income levels. For child characteristics, see Table 1.

#### 3.2. Physical activity levels across settings and time of week

Overall, children had a mean (SD) total PA level of 751 (199) cpm and spent 66 (21) min in MVPA per day. Children participated in more PA (all intensities) and less SED on weekdays compared to weekend days (p < 0.01) (Table 2). Fig. 1 illustrates how MVPA varied throughout an average week- and weekend day. There was a clear difference in pattern according to time of the week, with a peak of 7–8 min/h at 1 pm and 3 pm on weekdays, compared to generally lower levels and a less characteristic pattern on weekend days. When investigating the effect of preschool on children's PA levels, the specific preschool accounted for 5%–12% of the variance in children's PA and SED (ICC for full day/during preschool hours: TPA: 0.10/0.12; SED: 0.07/0.07; LPA: 0.12/0.12; MVPA: 0.05/0.06).

Most total PA and MVPA was accumulated during preschool hours, both in absolute values and values relative to accelerometer wear time, as illustrated in Fig. 2. Boys and girls spent, on average, 12% and 10% of their preschool day in MVPA, respectively. Moreover, 77% of children's total MVPA on weekdays was undertaken during preschool hours. However, after adjusting for wear time, MVPA only differed significantly between preschool hours and time out-of-care among boys (p < 0.05) (Table 2).

#### 3.3. Moderation of patterns according to sex, age, and overall MVPA

Table 3 gives an overview of the results regarding moderation of patterns across settings and time of week for sex, age, and overall MVPA. For the interaction of sex\*setting (i.e. preschool hours vs. time out-of-care), there were greater sex-differences during preschool hours compared to time out-of-care for total PA (p < 0.05), SED, LPA, and MVPA (p < 0.001). This indicated that preschool hours were associated with greater differences in PA between boys and girls relative to time spent out-of-care. Similarly, when testing the interaction sex\*time of week (i.e. weekdays vs. weekend days), we found greater sex-differences during weekdays compared to weekend days, but only for LPA and SED (p < 0.05).

With regard to the interaction of age\*setting, the difference in MVPA and SED between preschool hours and time out of care was greater in older children, with relatively more MVPA and less SED during preschool hours by increasing age (p < 0.001). Similarly, there was a significant interaction of age\*time of week with greater difference MVPA and SED on weekdays than on weekend days in older children (p < 0.001, p < 0.05).

Interaction analyses of overall MVPA (regardless of setting and/or time of week) and setting (overall MVPA\*setting) showed greater differences in both total PA, LPA, SED, and MVPA (p < 0.001) between preschool hours and time out-of-care with regard to higher levels of overall MVPA. Children with higher levels of overall MVPA had more total PA and MVPA, and less SED and LPA, during preschool hours compared to time out-of-care relative to children with lower levels of overall MVPA. Similarly, the interactions of overall MVPA and time of week (overall MVPA\*time of week) showed greater differences in MVPA and SED (p < 0.001) between weekdays and weekend days according to higher levels of MVPA, with relatively more MVPA and relatively less SED on weekdays compared to weekend days.

### 4. Discussion

Children spent more time in MVPA during preschool hours than during time out-of-care (NS difference in girls). Similarly, children were more physically active and less sedentary on weekdays than on weekend days. MVPA levels during preschool hours, relative to time out-of-care, were higher in boys, older children, and highly active children compared to girls, younger children, and children with lower levels of overall MVPA. Therefore, with regards to MVPA, some groups of children appear to benefit more from the preschool environment than others.

The preschool is important for children's MVPA in two ways. First, it is important in terms of actual time spent in MVPA during preschool hours because children spend a large amount of time in this arena throughout the week. Second, it is important in terms of relative amounts of MVPA adjusted for time, regardless of how much time children spent in preschool, as this arena promoted MVPA more than the out-of-care environment (Fig. 2). We observed peaks in MVPA at around 1:00 pm and 3:00 pm on weekdays (Fig. 1). This corresponded well with commonly scheduled outdoor-time in most of the preschools involved in our study, in which is associated with higher MVPA levels (Truelove et al., 2018).

Our findings showing higher activity levels during preschool hours compared to time out-of-care are in line with three previous studies from the UK, Denmark, and Sweden (Hesketh et al., 2015; Moller et al., 2017; Berglund and Tynelius, 2017), but in contrast to results from the US and Australia (Van Cauwenberghe et al., 2012; O'Dwyer et al., 2014; O'Neill et al., 2016). The conflicting results between studies could be explained by heterogeneity between samples, the amount of outdoor time, differences in policies or preschool environment, and/or in childcare attendance (e.g. hours per day in preschool), possibly affecting levels of PA. In Norway in general, as in the present study sample, almost all children attend preschool full time (97% of 3–5 year

**Table 2**

Mean values (SD) and differences ( $\beta$ , [95% CI]) in wear time, SED, and time in PA between weekdays and weekend days, and between preschool hours and time out-of-care.

	Time of week			Setting		
	Weekdays	Weekend days	Difference adjusted for wear time	Preschool hours <sup>a</sup>	Time out-of-care <sup>b</sup>	Difference adjusted for wear time
	Mean (SD)		$\beta$ (95% CI)	Mean (SD)		$\beta$ (95% CI)
<b>Total (n = 1109)</b>						
Wear time (min/day)	717 (44)	652 (66)	65 (61, 69)**	407 (14)	163 (19)	244 (243, 246)**
TPA (cpm)	753 (199)	719 (261)	57 (39, 75)**	823 (240)	633 (225)	102 (-41, 244)
SED (min/day)	347 (55)	333 (63)	-22 (-25, -18)**	179 (33)	91 (17)	-9 (-24, 7)
LPA (min/day)	298 (44)	257 (46)	16 (13, 18)**	183 (29)	59 (11)	-1 (-13, 11)
MVPA (min/day)	68 (22)	59 (23)	6 (5, 8)**	43 (15)	13 (5)	8 (1, 15)*
<b>Boys (n = 572)</b>						
Wear time (min/day)	720 (44)	659 (65)	61 (56, 67)**	407 (14)	164 (1)	243 (241, 245)**
TPA (cpm)	787 (203)	748 (254)	59 (34, 84)**	867 (255)	655 (16)	142 (-85, 369)
SED (min/day)	341 (54)	332 (60)	-22 (-27, -18)**	172 (32)	91 (17)	-10 (-32, 13)
LPA (min/day)	301 (42)	260 (45)	16 (13, 20)**	186 (28)	59 (11)	-4 (-20, 13)
MVPA (min/day)	74 (23)	64 (24)	6 (4, 8)**	47 (16)	14 (5)	12 (1, 22)*
<b>Girls (n = 537)</b>						
Wear time (min/day)	713 (43)	644 (67)	70 (64, 75)**	407 (14)	162 (20)	246 (244, 248)**
TPA (cpm)	718 (188)	689 (264)	54 (28, 80)**	776 (213)	610 (212)	43 (-128, 214)
SED (min/day)	354 (50)	335 (66)	-21 (-25, -16)**	186 (32)	91 (17)	-3 (-24, 18)
LPA (min/day)	293 (46)	253 (47)	14 (11, 18)**	181 (30)	58 (11)	0 (-17, 17)
MVPA (min/day)	62 (20)	53 (21)	6 (4, 8)**	39 (13)	12 (5)	2 (-7, 11)

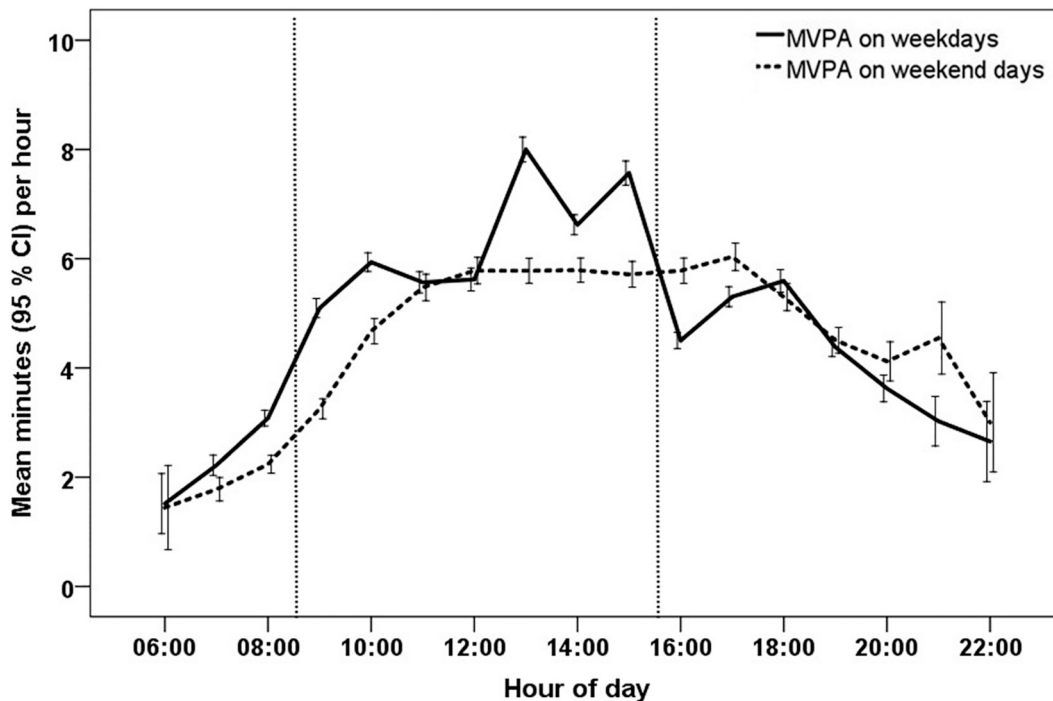
SD, Standard deviation. Unadjusted values are reported as mean (SD). The  $\beta$  coefficient represents the difference in wear time, min spent sedentary (SED), in light physical activity (LPA), and in moderate-to-vigorous physical activity (MVPA) per day, and the difference in total physical activity (TPA [cpm]), on weekdays vs. weekend days and during preschool hours vs. time out-of-care. Results from a three-level random intercept model adjusted for sex, age, BMI, parental education (highest level of mother or father), parental income level (highest yearly income of mother or father), season, and accelerometer wear time (min per day) when wear time was not the outcome, with “preschool” and “child” as cluster effects. The study was conducted in Sogn og Fjordane county, Norway, between September 2015 and June 2016.

<sup>a</sup> PS hours: Preschool hours (08:30 am–15:29 pm) on weekdays.

<sup>b</sup> Time out-of-care (morning 06:00–08:29 am and afternoon 15:30–23:59 pm on weekdays).

\* p < 0.05.

\*\* p < 0.01.



**Fig. 1.** Children's daily average moderate-to-vigorous physical activity (MVPA) per hour on weekdays (Monday-Friday) and weekend days (Saturday and Sunday). The vertical lines indicate preschool hours, defined as the hours between 08:30 am and 3:30 pm on weekdays. The study was conducted in Sogn og Fjordane county, Norway, between September 2015 and June 2016.

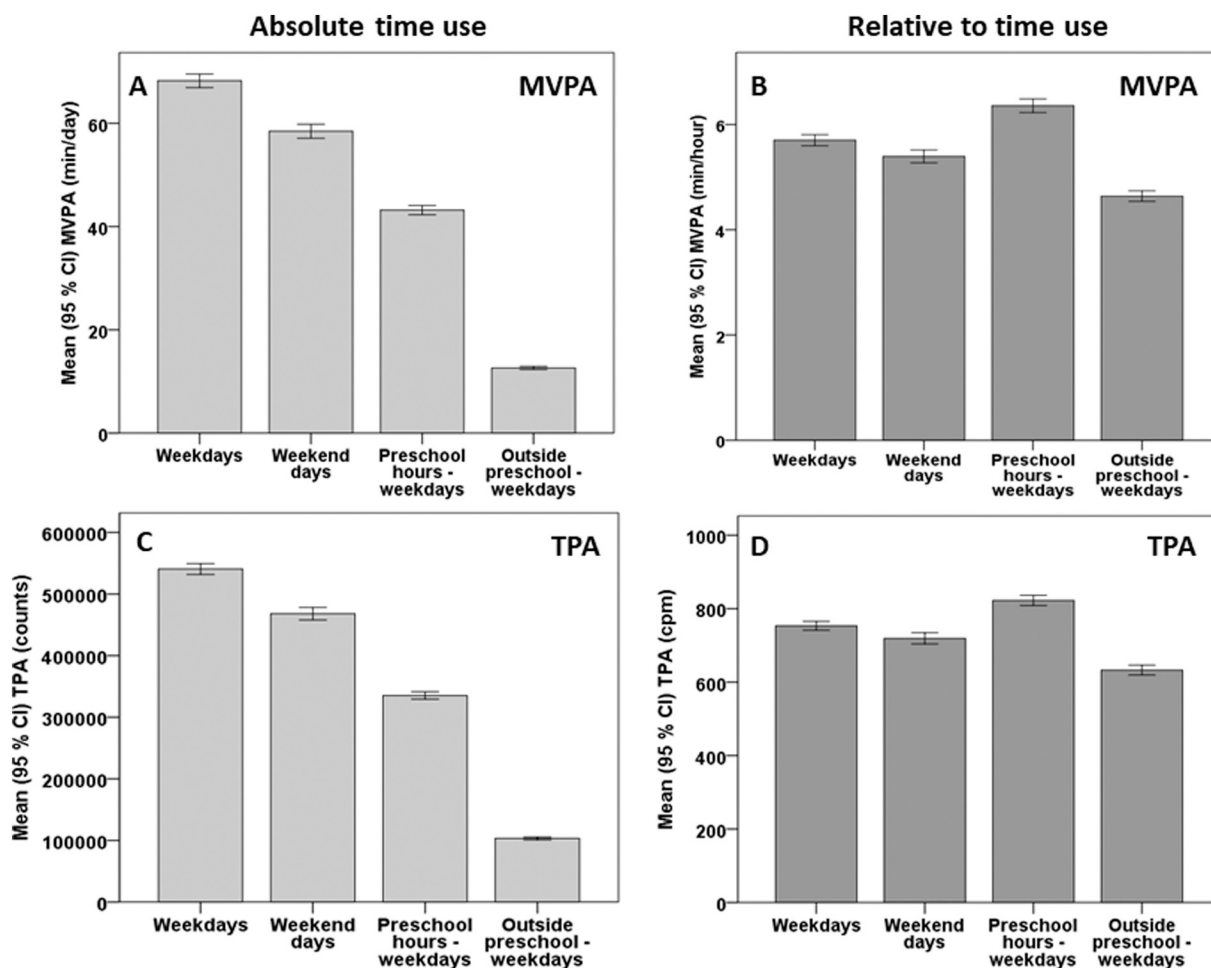


Fig. 2. Children's average MVPA (A, B) and total PA (TPA) (C, D) in absolute values (A, C) and values relative to accelerometer wear time (B, D). MVPA reported as minutes per day/minutes per hour, and total PA reported as counts/counts per minute. The study was conducted in Sogn og Fjordane county, Norway, between September 2015 and June 2016.

olds on a national level), i.e.  $\geq 33$  h per week (Statistics Norway, 2017). As the results of the present study are in line with results from other north-west European countries, we considered that differences in practice and attendance, for example in the US or Australia, are factors explaining the conflicting results, although additional comparative studies is needed to conclude in this matter.

Another aspect of the observed differences in setting-specific PA between studies is the variability in preschool environments within the same country or geographical area, which can lead to an inaccurate interpretation of the preschool's role for PA. In the present study, the specific preschool explains 5% of the variance in MVPA and 10% of the variance in total PA (cpm) (ICC). These percentages are in line with the median ICC reported in a systematic review by Finch et al. (Finch et al., 2016), and comparable with other European studies reporting on these specific variables (Hesketh et al., 2015; Olesen et al., 2014). In contrast, some US studies have shown that a specific preschool can account for up to 47% of the variance in children's MVPA (Finn et al., 2002; Pate et al., 2004). A low ICC in studies involving European countries may indicate that preschools in Europe are rather similar in terms of environmental factors and culture.

Substantial evidence shows that boys in general are more physically active and less sedentary than girls, and that sex-differences in PA are already present in preschool-aged children (Tonge et al., 2016). Our results support these conclusions, with a further suggestion that sex-differences in PA are also dependent on setting. We found that boys undertook relatively more PA and less SED when in preschool than girls

(e.g. a difference in MVPA for preschool hours vs. time out-of-care of 12 min for boys ( $p = 0.05$ ) vs. 2 min for girls, NS difference) (Table 2). Moller et al. and Hesketh et al. showed similar findings in terms of total PA (cpm), with boys exhibiting higher levels when in preschool compared to girls; however, they did not test interactions relative to time out-of-care (Hesketh et al., 2015; Moller et al., 2017).

As previously proposed by Hesketh et al., we believe that the opportunities for high-intensity play in the preschool environment might suit boys better than girls regarding sex-related activity preferences (Hesketh et al., 2015). The Nordic preschool model is characterized with a high focus on "learning through play" and children spend a considerable amount of time outdoors (Einarsdottir, 2013); therefore, we hypothesize that free outdoor play, in terms of MVPA, was more favourable to boys than to girls. Boys often prefer a more intensive, rough-and-tumble-play (Pellegrini and Smith, 1998) pattern than girls, who tend to prefer social, often light-intensity play (Barbu et al., 2011) that may vary less between the home and childcare environments, and could explain the observed differences in setting-specific MVPA between boys and girls. In contrast, Berglind and Tynelius found an opposite trend in their study of 4-year-old Swedish children. Their results showed that levels of SED and MVPA between the sexes were most apparent during time out-of-care on weekdays, indicating that girls are relatively more active and less sedentary than boys when in preschool, and less active and more sedentary during time out-of-care (Berglind and Tynelius, 2017).

To our knowledge, this is the first study to investigate interactions of

**Table 3**  
Interactions between settings and time of week and SED and sex, age, and overall MVPA levels.

	N = 1109, $\beta$ (95% CI)			
	Total PA (cpm)	SED	LPA	MVPA
Preschool hours vs. time out-of-care				
Sex*setting	p = 0.013	p < 0.001	p < 0.001	p < 0.001
Sex differences in preschool hours (girls vs. boys)	-77.9 (-105.5, -50.2)**	12.6 (8.9, 16.3)**	-5.4 (-8.3, -2.5)**	-7.3 (-9.0, -5.7)**
Sex differences in out-of-care (girls vs. boys)	-37.4 (-63.5, -11.2)**	1.5 (0.1, 3.0)*	-0.1 (-1.2, 1.1)	-1.4 (-2.0, -0.9)**
Age*setting	p = 0.259	p < 0.001	p = 0.524	p < 0.001
Preschool hours (change/year)	47.1 (30.5, 63.6)**	-1.9 (-4.1, 0.4)	-3.1 (-4.8, -1.4)**	5.1 (4.1, 6.1)**
Time out-of-care (change/year)	40.0 (23.7, 56.2)**	-0.6 (-1.5, 0.3)	-0.7 (-1.4, 0.01)	1.3 (1.0, 1.6)**
Total MVPA*setting	p < 0.001	p < 0.001	p < 0.001	p < 0.001
Preschool hours (change/min increase in total MVPA)	9.2 (8.7, 9.7)**	-1.0 (-1.1, -0.9)**	0.3 (0.3, 0.4)**	0.7 (0.6, 0.7)**
Time out-of-care (change/min increase in total MVPA)	7.3 (6.7, 7.9)**	-0.3 (-0.4, -0.3)**	0.2 (0.1, 0.2)**	0.2 (0.2, 0.2)**
Weekdays vs. weekend days				
Sex*time of week	p = 0.402	p = 0.026	p = 0.043	p = 0.112
Sex differences in weekdays (girl vs. boy)	-57.4 (-80.0, -34.8)**	15.1 (9.0, 21.1)**	-5.2 (-10.0, -0.4)*	-9.9 (-12.3, -7.5)**
Sex differences in weekend days (girl vs. boy)	-54.2 (-84.5, -23.9)**	10.32 (4.0, 16.6)**	-1.3 (-6.2, 3.6)	-8.8 (-11.4, -6.2)**
Age*time of week	p = 0.671	p = 0.016	p = 0.315	p < 0.001
Weekdays (change/year)	45.7 (30.7, 58.6)**	-2.6 (-6.3, 1.1)	-4.8 (-7.8, -1.8)**	7.6 (6.1, 9.1)**
Weekend days (change/year)	44.4 (26.3, 62.5)**	1.4 (-2.4, 5.1)	-6.5 (-9.4, -3.5)**	5.6 (4.0, 7.1)**
Overall MVPA*time of week	p = 0.089	p < 0.001	p = 0.016	p < 0.001
Weekdays (change/min increase in overall MVPA)	8.7 (8.4, 9.1)**	-1.7 (-1.8, -1.6)**	0.7 (0.5, 0.8)**	1.0 (1.0, 1.1)**
Weekend days (change/min increase in overall MVPA)	8.0 (7.3, 8.7)**	-1.4 (-1.5, -1.2)**	0.5 (0.4, 0.6)**	0.9 (0.8, 0.9)**

Highlighted p-values are derived from interaction analysis. The  $\beta$  coefficient (95% CI) represents the difference in min per day spent sedentary (SED), in light physical activity (LPA), and in moderate-to-vigorous physical activity (MVPA), and the difference in total physical activity (cpm), compared to the reference category (girls vs. boys) or as a change (per year; per minute increase in overall MVPA), for the associated setting/time of week. Final results from a three-level random intercept model adjusted for sex, age, BMI, parental education (highest level of mother or father), parental income level (highest yearly income of mother or father), season, and accelerometer wear time. Overall MVPA, mean all day MVPA regardless of setting or time of week. The study was conducted in Sogn og Fjordane county, Norway, between September 2015 and June 2016.

\* p < 0.05.

\*\* p < 0.01.

setting and time of week to age and overall MVPA levels within the preschool population. Despite relatively small differences, we found that the difference in MVPA and SED between preschool hours and time out-of-care was larger for older vs. younger children, in terms of relatively more MVPA and less SED when in preschool. These findings suggest that the age-related development in preschoolers' MVPA is linked more to factors within the preschool environment than to the out-of-care (home) environment. Further, it appears that the preschool arena affects children's MVPA increasingly with age, implying that older children (e.g. 5- to 6-year-olds) benefit more from this environment in terms of high-intensity activities than younger children (e.g. 3- to 4-year-olds). Additionally, we investigated whether PA in different settings was dependent on children's overall levels of MVPA (regardless of setting/time of week), and found that children with higher levels of overall MVPA had more total PA and MVPA during preschool hours compared to time out-of-care relative to children with lower levels of overall MVPA. These results suggest that highly active children undertake even more MVPA during preschool hours than children with lower overall MVPA levels. This finding is interesting as Moller et al. reported that less active children were substantially and consistently less active compared to highly active children, irrespective of the context (Moller et al., 2017). However, they did not investigate the relative difference between PA among children with high- or low-activity levels during preschool hours compared to time out-of-care.

Although previous studies have suggested that children's PA levels are determined mostly by genetic factors (Pate et al., 2004), our results and those of others (Hesketh et al., 2015; Van Cauwenberghie et al., 2012; O'Dwyer et al., 2014; Moller et al., 2017; Berglund and Tynelius, 2017; O'Neill et al., 2016) suggest that setting-specific factors (e.g. social and/or environmental factors) exert an important influence on children's PA levels which, in turn, are dependent on individual factors such as sex and age.

As PA levels are known to decrease over time in school-aged

children and adolescents (Cooper et al., 2015), the preschool years are a critical period to ensure sufficient levels of PA throughout childhood (Goldfield et al., 2012). Previous studies have highlighted the home environment as an important arena for PA promotion in preschool-aged children, as this seems to be an arena with great potential to increase MVPA levels (Hesketh et al., 2015; Moller et al., 2017; Berglund and Tynelius, 2017). The lower MVPA levels at home compared to preschool hours showed herein, is consistent with this view. However, although we recognize the home environment as an important arena for young children's PA, we consider the preschool arena as an ideal setting for PA promotion because of its unique opportunity for structured PA for all children, irrespective of children's characteristics and parents' behaviours, attitudes, resources, and socio-economic background.

## 5. Strengths and limitations

The present study had a large sample size, a wide age range, a high response rate, good compliance with the accelerometer protocol, and a long PA monitoring period, which are major strengths. Due to the considerable week-by-week variability observed when measuring PA by accelerometry in preschool children (Aadland and Johannessen, 2015), a long registration period (> 7 days) will increase the reliability of the accelerometer measurements (Aadland and Johannessen, 2015) and, thus, increase the validity of the study conclusions. Therefore, the 14-day PA monitoring protocol applied herein is considered an important strength of the study.

Accelerometer data are, however, not without limitations (Cain et al., 2013). In addition to challenges relating to cut-points and other methodological considerations, the accelerometer do not correctly capture certain activities (e.g. cycling or swimming). Furthermore, the accelerometer does not provide information about the type of PA or the context in which the PA was conducted, which would have been valuable information when studying PA patterns within different settings.

Another limitation of the present study is the use of standardized times for defining in- and out-of-preschool, which might have introduced some misclassification of time use. However, although some random errors may have been introduced, estimates were based on the means of attendance; thus, we consider that the results were not biased through our choice of time categories. Further, the average parental educational level among the included children was higher than among the excluded children, and almost all the participating children were born in Norway. This means that caution should be exercised in generalising the results to populations comprising ethnic minorities or populations with lower SES, including other Norwegian populations.

## 6. Conclusion

The present study adds to the limited evidence on how different settings influence preschoolers' PA, and highlights the importance of the preschool arena for children's MVPA. Norwegian preschoolers are overall more physically active during preschool hours than during time out-of-care and, similarly, more active on weekdays compared to weekend days. Children's PA levels are further dependent on individual factors, such as sex, age, and overall MVPA levels. Our results indicate that the preschool environment stimulates boys, older children, and highly active children more successfully in terms of higher MVPA levels. Awareness of these differences and greater encouragement for girls, younger preschoolers, and less active children to participate in moderate-to-high-intensity activities during preschool hours may, therefore, be warranted.

## Conflicts of interest

None.

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