Children's physical activity and the preschool physical environment

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Children's physical activity and the preschool physical environment: The moderating role of gender

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ABSTRACT

The physical environment in preschool, covering all indoor and outdoor equipment, and the surfaces of the preschool yard, may have a large potential for increasing children's physical activity (PA). However, it is less clear which specific physical environmental factors are associated with children's PA. Cross-sectional associations between the individual observed items (e.g. fixed and portable equipment, surfaces, terrain in the grounds) as well as composite scores for the PA equipment on the one hand, and children's PA, measured by accelerometers, on the other, were investigated in a sample of 3–6 year old children (N = 778) attending preschool in Finland. Having balance equipment and trampolines in group facilities, having balance equipment, gym mats and sticks in the gym and having skipping ropes, sand and mostly hilly terrain on the outdoor playground were associated with children's higher PA, regardless of gender. On the contrary, having gravel as the terrain in the playground and having a seesaw outdoors were associated with lower PA levels, regardless of gender. Four significant interactions with gender were found, but none of the environmental predictors remained significant in the post-hoc gender-stratified analyses. Variety in PA equipment and playground terrain may be beneficial for increasing children's PA in preschools.

1. Introduction

Frequent physical activity (PA) in early childhood is associated with better physical, social and psychological health (Timmons et al., 2012). The preschool-age (ages 3–6 years) is a period of particularly rapid development and learning. For instance, competence in multiple motor skills, a prerequisite for PA, is developed in this period (Logan, Kipling Webster, Getchell, Pfeiffer, & Robinson, 2015; Stodden et al., 2008). The development of motor skills requires continuous interaction with a stimulating indoor and outdoor physical environment, including attractive and sufficient space, availability of play equipment (e.g., fixed and portable) and variety of surfaces (e.g., natural elements, artificial coverings) (Wick et al., 2017). Children who develop motor skills earlier are also more likely to be active (Loprinzi, Cardinal, Loprinzi, & Lee, 2012; Loprinzi, Davis, & Fu, 2015; Stodden et al., 2008), and better motor skills in early childhood also support children's cognitive and social development (Haapala, 2013). Moreover, higher and more frequent engagement in PA at a preschool-age is associated with the accelerated development of motor skills (Barnett, Salmon, & Hesketh, 2016; Stodden et al., 2008). However, most preschool children lag behind the required amounts of daily PA, as at least three hours of activity (light, moderate or vigorous) is recommended (Beets, Bornstein, Dowda, & Pate, 2011; De Craemer et al., 2015; Okely, Trost, Steele, Cliff, & Mickle, 2009; Pate et al., 2015; Tucker, 2008). There is therefore a need to identify methods for modifying the

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preschool physical environment in order to provide opportunities for all children to improve their motor skills and increase their PA levels.

1.1. Physical activity in preschool

Preschool is an important setting for boosting children's daily PA. Previous studies have demonstrated that the preschool setting can account for 14–47 percent of the variance in children's PA after controlling for individual-level factors (Olesen, Kristensen, Korsholm, & Froberg, 2013; Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004; Pate, McIver, Dowda, Brown, & Addy, 2008; Reilly, 2010). The majority of children in developed countries attend institutional early education facilities, such as preschools, almost every day of the working week (OECD, organisation for economic Cooperation and Development, 2016), and Finland is no exception (National Institute for Health and Welfare, 2016). About 80% of Finnish 3-to-5-year-olds and almost 100% of six-year-olds, from various socioeconomic and cultural backgrounds, attend full-day preschool (National Institute for Health and Welfare, 2016). This makes the preschool setting a promising place to promote PA. Current national Finnish early-childhood policy also states that preschools should offer stimulating physical environments for children's active play and the development of healthy lifestyles, both indoors and outdoors (Finnish National Agency for Education, 2016). Nonetheless, children are only vigorously physically active for approximately 10 percent of each preschool day in Finland, while they are physically active at any intensity level for less than 50% of their daily time outdoors (Tammelin et al., 2016). In addition, children's PA in preschools seems to be inadequate to support the development of fundamental motor skills (Iivonen et al., 2016). There is therefore a need for more research on the preschool characteristics that influence children's PA.

1.2. Environmental factors and level of PA

Socioecological models state that several factors, such as social interaction between early educators and children, policy regulations, and the physical environment, may influence children's PA in the preschool setting (Bronfenbrenner, 1979; Gubbels, Van Kann, de Vries, Thijs, & Kremers, 2014; Stokols, 1996). According to a recent review, the aspect most frequently studied in preschools is the physical environment (Tonge, Jones, & Okely, 2016). The review concludes that a total of 12 physical environment variables are associated with children's PA, the strongest positive associations being with the availability of an outdoor environment in preschool and the size of the play space (Tonge et al., 2016). However, Tonge et al. (2016) conclude that other aspects of the physical environment, such as natural features and surfaces, the presence of hills, shade, portable equipment, and fixed equipment, had either no association or the results were inconclusive (Tonge et al., 2016). Another review focusing on preschool children's playground characteristics concluded that having sufficient space to play and having optimal playground conditions, including an open field, longer recess duration and less supervision, were associated with higher PA levels for preschool children (Broekhuizen, Scholten, & de Vries, 2014). However, most of these studies have used composite scores to describe the physical environment. These may offer an illustration of the general quality level of the preschool physical environment, but they fail to provide information about which specific environmental factors can be beneficial for increasing PA. Distinct equipment and surfaces can have different associations with children's PA levels. For instance, Gubbels et al. recognized that riding toys and a small play area were associated with lower indoor PA levels (Gubbels, Van Kann, & Jansen, 2012). In addition, portable slides, fixed swinging equipment and sandboxes were associated with lower outdoor PA levels, whereas the availability of portable jumping equipment and the presence of a structured track in the playground were associated with higher outdoor PA levels (Gubbels et al., 2012). This study was, however, conducted among children aged 2–3 years. Children aged 3–6 years have more developed motor skills, and therefore better capabilities for different types of PA, suggesting different associations between specific physical environmental factors and PA in this age group.

1.3. The role of gender

It is well known that preschool-aged boys are more active than girls (Bingham et al., 2016; Hesketh et al., 2016). Although gender is not a modifiable characteristic in behavioral interventions, tailored environmental interventions can be designed when the gender-specific factors associated with PA are recognized. Nevertheless, gender-specific associations between physical environmental factors and children's PA are rarely studied. One study focusing on preschool recess time nevertheless ascertained that hard playground surfaces were associated with higher PA for boys (Cardon, Van Cauwenberghe, Labarque, Haerens, & De Bourdeaudhuij, 2008). Another study (Hinkley, Salmon, Crawford, Okely, & Hesketh, 2016) similarly found a number of gender-specific associations between physical environment characteristics and PA. Of these, the number of spaces with natural ground covering, the number of constructed resources and the number of pieces of portable equipment were significantly associated with boys' PA levels, whereas outdoor PA space and total PA space were associated with girls' PA levels (Hinkley et al., 2016).

1.4. Current study

This study has two aims: 1) to explore which preschool physical environmental factors (both specific and composite scores) are associated with preschool children's total PA, and 2) whether gender moderates the associations between these factors and preschool children's total PA. We hypothesize that children's gender moderates the associations between the preschool physical environmental factors and children's PA. Children's age and study season are often recognized important factors associated with children's PA (Bingham et al., 2016), and therefore, these factors will be taken into account. In Finland, municipalities are responsible for organizing early education and care services (ECE) based on national guidelines (The Finnish National Agency of Education, 2017), and therefore, municipality level is taken into account.

2. Methods

2.1. Study context

Each child in Finland has the right to early childhood education. Families pay fees that in full-day provision vary between 0 and 290€ per month (as of 2017), depending on the size and income of the family. Most children attend municipal-based preschools, whereas private preschools are rare in Finland. The Finnish ECE model is based on learning by playing, and compulsory pre-primary education in preparation for official schooling begins at the age of six. Learning by playing means for instance that children have free playing times without educator instructions (at least 30 min per each playing time) when children can choose activities they like to be involved in, outdoors or indoors. Children also have compulsory outdoor time, usually twice a day (The Finnish National Agency of Education, 2017). In this study, we use the word 'preschool' to describe formal municipal-based institutional early education provided outside the home.

2.2. Participants

This study is part of the DAGIS (Increased Health and Wellbeing in Preschools) study. More about the study and its procedures can be found elsewhere (Määttä et al., 2015). As part of this overall project, a cross-sectional study was conducted between September 2015 and April 2016. Municipalities with a larger variety in education and income levels with a higher Gini coefficient (the measure of income inequality among the population in a municipality) according to national statistics (National Institute of Health and Welfare, 2016) were selected. In total, eight (75%) of the 12 municipalities contacted in Southern and Western Finland participated in this study. Preschools were randomly selected within the participating municipalities. The participating preschools were required to have at least one preschool group with 3-to-6-year-olds. In total, 86 of the 169 preschools contacted (56%) were willing to participate in this study. In total, 16 preschools (19% of preschools willing to participate) were excluded because their official spoken language was neither Finnish nor Swedish, or because they were open 24 h a day. Preschool groups providing pre-primary education exclusively for 6-year-old children were also excluded. In addition, we excluded preschools in which less than 30 percent of the children in one preschool group participated in the study. Of the consenting preschools, 20 failed to reach the required 30 percent participation rate. Therefore, the study was conducted in 66 preschools (39% of those invited). These preschools had a total of 159 preschool groups (range between one to five groups in one preschool) with children aged 3–6 years.

Of the participating preschools, 3592 parents with children aged 3–6 years were asked to participate. A total of 983 parents agreed to participate in the study (27% consent rate). Of these, 91 parents had a child in a preschool group that failed to achieve the 30% consent rate and were therefore excluded. In addition, 28 consenting families failed to provide any data. Therefore, a total of 864 children and their parents (24% of those invited) participated in the cross-sectional study. The average age of the participating children was 4 years and 4 months (standard deviation 10 months). Of the participating children, 48% were girls and 29% of children had mother with high educational background (at least master's degree). A total of 82% of children were at least four days a week in the preschool, and 89% of children were at least 7 h per day in preschool. The University of Helsinki Ethical Review Board in the Humanities and Social and Behavioral Sciences approved the study procedures.

3. Measures

3.1. Physical environment

The physical environment was measured using a comprehensive observation instrument that was purposely designed for this study and suitable for the Finnish context. This instrument consisted of a selection of items from the Environment and Policy assessment and Observation Instrument (EPAO) (Ward et al., 2008), items from the National investigation about the PA conditions in Finnish preschools (Ruokonen, Norra, & Karvinen, 2009), and some additional items developed to meet the aims of this study. All six research assistants in the study were trained to use this instrument by the responsible researcher. Each preschool was simultaneously and independently observed by two research assistants. After each observation, the research assistants discussed their ratings to reach consensus on the findings. The inter-rater reliability between different research assistants was not checked.

Some general guidelines were set for the observations. Assistants were asked to check all the possible closets and rooms in the indoor facilities. Moreover, they were advised to consult early educators if, for instance, they encountered difficulties in opening the outdoor equipment sheds or in observing some items. If preschools lacked a gym but had a separate PA equipment storage room inside (not in the group facilities), the assistants listed the equipment in this storage area as PA equipment in the gym. When observing equipment and PA-promoting elements in the playground, all the possible items were checked. The research assistants were instructed not only to mark all the equipment/surfaces listed on the observation sheet, but also to take account of any other possible items relevant to the observed category and mark them in the open space provided after each category. Based on these open-space items, the following additional equipment was included in the analyses: trampolines, big balls and sticks in group facilities, games and play equipment in the gym, and snow pushers in the playground.

The preschool physical environment related to PA opportunities was assessed according to the following categories: PA equipment in group facilities (10 items), fixed equipment indoors (5 items), Gym in the preschool, PA equipment in the gym (15 items), surfaces in the preschool grounds (9 items), terrain in the playground, shady areas in the playground, fixed PA equipment in the preschool yard (9 items), PA-promoting elements in the playground (6 items), and portable equipment in the playground (8 items). The items measured in each category are presented in more detail in Table 1.

For PA equipment in the preschool's group facilities, the form had three answer options: yes, in view; yes, in the closet, and none at all. This was recoded as either present (1) or none at all (0). All other equipment was measured as either available (1) or not available (0). When evaluating the terrain and shadiness of the playground, only one option per yard could be selected. Possible answers for the terrain were mostly flat, mostly hilly or a combination of both. The shadiness of the play area was evaluated with three answer options: shadows on the play area, shadows at the sides and no shade at all.

From the individual equipment items, we formed five composite scores to illustrate the total amount of equipment indoors and outdoors. The recommendations of the EPAO observation sheet were followed when forming the composite scores (Bower et al., 2008). Firstly, the composite scores were formed for each equipment category (equipment in group facilities, fixed equipment indoors, equipment in the gym, fixed equipment in the preschool yard, and portable equipment in the playground). The items in each category were summed and divided by the number of items and then multiplied by 10 so that the maximum score in each equipment category was 10. Secondly, total scores were formed for indoor and outdoor equipment. All the items in each equipment category were summed and divided by the number of items and then multiplied by 10, so that the maximum score in each equipment category was 10. Next, equipment in the preschool's group facilities, fixed equipment indoors and equipment in the gym were summed to form the adjusted composite score for indoor equipment. Similarly, portable and fixed equipment outdoors were summed to form the adjusted composite score of outdoor equipment.

3.2. Children's physical activity

The children wore Actigraph wGT3X-BT accelerometers for seven days, 24-h a day. The research assistants fit the accelerometers around the children's waist in the preschool, and the parents received written instructions about the use of the accelerometer. Preschool-hours were separated from home hours based on the parent-completed diary. In line with previous research, a child should have attended preschool for two days during the measurement week to be included in the study and should have worn his or her accelerometer for a minimum of 240 min during preschool hours (Byun, Beets, & Pate, 2015; Hinkley et al., 2012; Rich et al.,

Table 1
Descriptive statistics of preschool physical environment items used in the DAGIS study.

Physical environment context	Physical environment item	% of yes	No. of yes answers on a preschool group level	Total no. of observed preschool groups
PA equipment in the preschool's group facilities				
	Balls	48.6	69	142
	Gym mats	31.4	44	140
	Spinning equipment	26.2	37	141
	Bean bags	20.4	29	142
	Parachute	9.9	14	141
	Balance equipment	15.0	21	140
	Crawling tunnel	16.4	23	140
	Trampoline	5.2	7	135
	Big balls	6.7	9	135
	sticks	7.4	10	135
Fixed equipment indoors				
	Soft area for playing	58.2	85	146
	Stall bars	84.9	135	159
	Climbing wall or other climbing place	60.1	92	153
	Floor marks	70.9	107	151
	Pool/Water play equipment	40.3	58	144
Gym in the preschool		72.3	115	159
PA equipment in the gym				
	Balls	98.4	123	125
	Skipping ropes	91.8	112	122
	Balance equipment	92.6	113	122
	Riding toys	37.5	45	120
	Sticks	91.9	114	124
	Gym mats	89.6	112	125
	Parachute	87.2	109	125
	Bean bags	86.8	105	121
	Exercise balls	52.5	64	122
	Trampoline	81.7	107	131
	Crawling tunnel	77.0	94	122
	Hoops	80.0	100	125
	Movable floor markers	66.4	81	122
	Hopper balls	59.0	72	122
	Game equipment	73.8	90	122
Surfaces in the preschool grounds				
	Asphalt	49.4	78	158
	Grass	79.1	125	158
	Gravel	82.3	130	158
	Sand	88.0	139	158
	Safety surfacing	24.7	39	158
	Rocks	34.8	55	158
	Forest	6.3	10	158
	Trees	72.8	115	158
	Tiling	56.3	89	158
Terrain on the playground				
	Mostly flat	62.7	99	158
	Mostly hilly	2.5	4	158
	Combination of both	36.7	58	158
Shady areas on the playground				
	At the sides	74.7	118	158
	In the play areas	58.2	92	158
	No shade	7.6	12	158
PA-promoting elements in the playground				
	Soccer field	19.9	31	156
	Open area suitable for playing	99.4	157	158
	Ball wall	46.8	73	156
	Basketball hoop	32.7	51	156
	Track area for riding toys	77.7	122	157
	Outdoor play paintings on the ground	12.1	18	149
Fixed PA equipment in the preschool yard				
	Sandbox	98.7	157	159
	Playhouse	37.2	58	156
	Swings	100	159	159
	Spring swings	74.5	117	157
	Seesaw	45.3	72	159
	Climbing frames	93.1	148	159
	Slides	92.4	145	157
	Balancing equipment	66.2	102	154
	Merry-go-rounds	17.2	26	150

Table 1 (*Continued*)

Physical environment context	Physical environment item	% of yes	No. of yes answers on a preschool group level	Total no. of observed preschool groups
Portable PA equipment in the playground				
	Balls	96.2	153	159
	Skipping ropes	71.5	113	158
	Balance equipment	82.4	131	159
	Riding toys	97.5	155	159
	Sticks	80.3	126	157
	Goals	66.5	103	155
	Sleds	94.7	144	152
	Snow pushers	69.0	107	155

2013). Due to children's spontaneous and intermittent activity patterns (Rowlands and Eston, 2007), a 15-s epoch length (defined as sampling interval that summarizes all registered counts during this period) was chosen when downloading data from the Actigraphs. Non-wear time was set at 10 min of consecutive zeros or more. Evenson cut points were applied (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008). In this study, we used total PA – from light to vigorous intensity – as an indicator of PA. The cut point for PA was thus at least 101 counts per minute, combining light (between 101 and 2295 counts per minute), moderate (between 2296 and 4011 counts per minute) and vigorous (4012 and above per minute) activity (Evenson et al., 2008). Total PA minutes per hour were calculated to account for the varying lengths of time children spent in preschool.

In total, 821 children (95% of the participants) wore the accelerometer for one week. Of these, 778 (95%) had sufficient valid hours and days in order to be included in the study. The average wear time during preschool was 419 min (standard deviation 56 min). There were no statistically significant gender, age or socioeconomic status differences between children who had valid data during preschool hours and those who did not (all p values >0.05).

3.3. Covariates

The analyses were adjusted for children's age, gender, and season of measurement. Due to large seasonal variations in weather and its possible influence on children's PA, the season of measurement was used as a covariate. The season of measurement was devided into three groups due to variation in weather conditions (1 = September–October, 2 = November–December, and 3 = January–April). Data regarding 44% (n = 379) of the included children were collected during the months of September and October, 36% (N = 310) during November and December, and the remaining 20% (N = 175) between January and April.

In addition, multivariate analyses were adjusted for municipality. Municipality was treated as a dummy variable in the analyses. However, all the participating preschools in certain municipalities had all the observed PA equipment in the gym, which meant that no variation existed in the analyses when adjusting for municipality. Therefore, when analyzing the associations between PA equipment in the gym and children's PA, we did not adjust for municipality.

3.4. Statistical methods

SPSS version 23 (SPSS Inc.,Chicago, IL, USA) was used for the descriptive statistics and Mann-Whitney U-test. The main analyses were conducted in three steps (Frazier, Tix, & Barron, 2004). Firstly, in step one, the main effects were examined using linear regression models, clustered within the preschool group, to explore the associations between preschool physical environmental factors and children's PA. Secondly, in step two, moderator effects were examined by additionally including the main effect of gender (the moderator) into the linear regression models, followed by the interaction between each of the independent variables and gender. In case there was a significant moderator effect of gender in step two (defined as $p < 0.05$ for the interaction term), post-hoc analyses were performed in step three. The sample was then stratified by gender, and linear regression analyses examining the main effects (in line with step 1) were performed to examine the main associations separately for boys and girls (Frazier et al., 2004). All the linear regression analyses were conducted in Mplus 7.1 (Muthén & Muthén, 2017). The maximum likelihood estimation with robust standard errors (MLR) was used as an estimator.

4. Results

On average, the participants spent 33.5 min (standard deviation 5.1 min) engaged in PA per hour in their preschool. Of this total PA, an average of 27 min consisted of light activities, 4.5 min of moderate activities and 2 min of vigorous activities. Boys had an average of 34.3 min (standard deviation 4.9 min) total PA per hour, whereas for girls the average total PA per hour was 32.7 min (standard deviation 5.3). A Mann-Whitney U-test indicated that boys (*Mdn* = 34.3) had significantly higher minutes of total PA per hour than girls (*Mdn* = 32.1), $U = 4.96$, p value <0.001.

Table 1 displays the descriptive statistics for the physical environment items. All the preschools had swings in the yard. One preschool group lacked an open space suitable for playing in the yard. Similarly, all but two of the preschools groups had balls in the gym and a sandbox in the yard. Due to these non-variations in swings, an open space suitable for playing, balls in the gym and a sandbox in the yard, these items were excluded from the final analyses. Table 2 provides the descriptive statistics for the composite scores of PA equipment.

4.1. Associations between physical environment and children's total PA

Table 3 describes the main effects of the associations between the physical environmental factors and the children's PA. Among the preschool group facilities, having balance equipment (β = 1.89, 95% CI: 0.12, 3.65) and having a trampoline (β = 2.30, 95% CI: 0.61, 3.98) were associated with higher PA. Having balance equipment (β = 3.47, 95% CI: 0.64, 6.30), sticks (β = 2.16, 95% CI: 0.38, 3.94) and gym mats (β = 2.08, 95% CI: 0.57, 3.59) in the preschool gym, having skipping rope in the yard (β = 1.59, 95% CI: 0.24, 2.94), sand as a surface in the preschool ground (β = 1.66, 95% CI: 0.23, 3.09) and a predominantly hilly landscape in the preschool yard (β = 2.07, 95% CI: 0.91, 3.23) were all associated with higher PA minutes during preschool hours. By contrast, having gravel as a surface in the preschool grounds (β = −1.87, 95% CI: −3.38, −0.36) and having a seesaw in the yard (β = −1.63, 95% CI: −2.63, −0.63) were associated with lower PA minutes during preschool hours.

Table 2
Descriptive statistics of composite scores for equipment in different contexts in the preschool setting in the DAGIS study.

Composite score for equipment in certain context	Mean	Standard deviation	Observed score range	Potential score range
PA equipment in the group facilities	2.06	2.51	0–10	0–10
Fixed equipment indoors	2.98	1.34	0–5	0–5
PA equipment in the gym	11.54	2.35	3–15	0–15
Adjusted total amount of equipment indoors[a]	12.99	5.14	0–22.67	0–30
Fixed PA equipment in the preschool yard	6.18	1.3	2–9	0–9
Portable PA equipment in the playground	6.41	1.28	0–8	0–8
Adjusted total amount of equipment outdoors[b]	14.88	2.34	4.44–18.89	0–20

[a] All the items of PA equipment in the group facilities, fixed equipment indoors or PA equipment in the gym were summed, divided by the number of items, and multiplied by 10 so that maximum score for each item category is 10.
[b] All the items of fixed PA equipment in the preschool yard and portable PA equipment in the playground were summed and divided by the number of items, and multiplied by 10 so that maximum score for each item category is 10.

4.2. Moderating effect of gender in associations between physical environment and children's total PA

Table 3 presents the moderator effect of gender in the associations between the physical environment and children's total PA in preschool. There were four significant moderator effects between gender and physical environmental factors in relation to children's PA: gender interacted with gym mats in the preschool's group facilities (β = 1.50, 95% CI: 0.19, 2.81), stall bars indoors (β = −2.21, 95% CI: −3.71, −0.71), bean bags in the gym (β = 2.58, 95% CI: 0.23, 4.94), and slides in the preschool yard (β = −2.46, 95% CI: −4.29, −0.62). These are presented graphically in Fig. 1. However, the post-hoc analyses revealed that none of the associations remained significant when stratified by gender. Gym mats in the group facilities were not significantly associated with neither girls' (β = −0.02, 95% CI: −1.53, 1.49) nor boys' PA (β = 0.98, 95% CI: −0.47, 2.43). Indoor stall bars were not significantly associated with girls' PA (β = 0.24, 95% CI: −1.46, 1.95) or with boys' PA (β = −1.19, 95% CI: −2.63, 0.25) either. Similarly, pea bags in the gym were not significantly associated with girls' PA (β = −0.03, 95% CI: −3.04, 2.99) or boys' PA (β = 1.58, 95% CI: −1.74, 4.89). Finally, having slides in the preschool yard was not significantly associated with girls' PA (β = 1.61, 95%CI: −0.63, 3.85) or boys' PA (β = −0.23, 95% CI: −2.34, 1.87) either.

5. Discussion

This study aimed to explore the associations between children's total PA and various factors in the preschool physical environment. In addition, the study explored whether a child's gender moderated these associations. We hypothesized that gender would moderate the associations between preschool physical environmental factors and children's PA. A range of physical environmental factors were associated with children's PA during preschool hours. Having balance equipment and a trampoline in the group facilities, having balance equipment and gym mats in the gym, and having skipping ropes outdoors were associated with higher PA, regardless of the child's gender. In addition, sand as a surface in the preschool grounds and a predominantly hilly terrain in the preschool yard were also associated with higher PA. Conversely, seesaws and having gravel as an outdoor surface were associated with lower levels of PA. A significant interaction with gender was found for the following items: gym mats in group facilities, stall bars indoors, bean bags in the gym, and slides outdoors. However, perhaps due to insufficient power, none of the variables in the gender-stratified analyses were significantly associated with children's PA.

Our study suggests that it is beneficial to have many different types of equipment both indoors and outdoors in preschools. Nonetheless, equipment related to jumping or balancing skills seems to be particularly associated with higher PA. This finding is in line with Gubbels, who found that portable jumping equipment was positively associated with children's PA in preschools (Gubbels et al., 2012). Although it was not a research purpose itself, an interesting finding was that only about five percent of preschool groups had trampolines in group facilities. Having a trampoline in a preschool group was associated with higher PA levels. A trampoline may be an indicator of the level of PA equipment in preschools, especially in their group facilities. It may also mean that these preschool's group facilities are more spacious, thereby allowing trampolines to be safely used inside. Early educators have often mentioned the lack of space indoors as a hindrance for increasing indoor PA (Fees, Trost, Bopp, & Dzewaltowski, 2009; van Zandvoort, Tucker, Irwin, & Burke, 2010). Similarly, many preschools have safety regulations and rules that limit vigorous activities such as jumping and running (Copeland, Sherman, Kendeigh, Kalkwarf, & Saelens, 2012). It was outside the scope of this study to investigate the associations between the social environment in preschool and children's PA. However, future research should study in greater depth the potential interaction between the physical environment (e.g. indoor space, equipment) and the social environment (e.g. rules and regulations related to safety issues) and its consequent influence on children's PA levels.

We identified only one piece of equipment, the seesaw, which was associated with lower PA levels. This finding could be explained by the fact that children usually sit when playing on a seesaw. Gubbels similarly found that sandboxes were associated with lower PA levels (Gubbels et al., 2012). However, we were unable to assess the association between sandboxes and children's PA because all the preschools in our study had a sandbox. Furthermore, it should be noted that children's PA was measured by a device worn around the waist, and consequently upper-body movements might have been poorly detected (Hills, Mokhtar, & Byrne, 2014). Therefore, the associations we found between children's PA and equipment related to throwing and catching may be invalid. Nonetheless, this type of equipment is clearly beneficial for developing fine motor skills, which in turn are beneficial for PA skills (Gallahue, Ozmun, & Goodway, 2011). In a preschool setting, a wide variety of equipment may therefore be beneficial for children's motor skills and PA levels, but also for children's social and cognitive development (Haapala, 2013).

The results of our study indicated that none of the composite scores for PA equipment was associated with children's PA. When using composite scores for portable and fixed equipment, other studies have produced mixed findings for the associations between equipment and children's PA (Tonge et al., 2016). One reason for such findings may be that these composite scores are constructed from pieces of equipment that are associated with either higher or lower PA. Using composite equipment scores may therefore hide the significant associations between children's PA and individual pieces of equipment. Overall, our findings support the measurement of associations between children's PA and distinct, individual pieces of equipment, which can provide more accurate knowledge for use in future PA-promotion projects. This information

Table 3
Associations between factors in the preschool physical environment and children's total physical activity (PA, min/hour) in preschool, and the moderator effects of gender in the DAGIS study.

	Total PA min/hour					
	Main effects[a]			Moderator effects[b]		
	β	Lower 95% CI	Upper 95% CI	β	Lower 95% CI	Upper 95% CI
PA equipment in the group facilities						
Balls (N = 750)	0.35	−0.95	1.64	0.84	−0.49	2.17
Gym mats (N = 735)	0.75	−0.55	2.04	**1.50**	**0.19**	**2.81**
Spinning equipment (N = 732)	0.14	−0.86	1.14	0.24	−1.27	1.75
Bean bags (N = 745)	0.15	−1.56	1.85	0.68	−0.78	2.14
Parachute (N = 737)	1.16	−1.12	3.43	−1.39	−3.78	1.00
Balance equipment (N = 730)	**1.89**	**0.12**	**3.65**	−0.15	−1.74	1.44
Crawling tunnel (N = 730)	1.46	−0.32	3.23	0.64	−1.04	2.33
Trampoline (N = 710)	**2.30**	**0.61**	**3.98**	−2.05	−4.50	0.39
Big balls (N = 710)	0.80	−0.67	2.28	1.14	−1.64	3.92
Sticks (N = 710)	−0.04	−1.80	1.72	1.54	−0.64	3.73
Total amount of PA equipment in the group facilities (N = 778)	0.18	−0.09	0.46	0.11	−0.16	0.38
Fixed equipment indoors						
Soft area for playing (N = 728)	0.73	−0.75	2.21	−0.27	−1.68	1.34
Stall bars (N = 778)	−0.10	−1.51	1.31	**−2.21**	**−3.71**	**−0.71**
Climbing wall or other climbing place (N = 746)	−1.00	−2.09	0.09	0.64	−0.74	2.01
Floor marks (N = 751)	0.55	−1.22	2.32	0.94	−0.59	2.48
Pool/Water play equipment (N = 706)	0.29	−1.12	1.69	−0.18	−1.52	1.16
Total amount of fixed equipment indoors (N = 778)	0.07	−0.21	0.34	0.02	−0.20	0.24
Total amount of equipment in group facilities and fixed equipment indoors (N = 778)	0.15	−0.08	0.38	0.07	−0.16	0.30
Gym in the preschool (N = 778)	0.81	−1.17	2.79	0.08	−1.28	2.81
PA equipment in the gym[c]						
Skipping ropes (N = 571)	1.97	−0.01	3.96	0.77	−1.93	3.48
Balance equipment (N = 568)	**3.47**	**0.64**	**6.30**	1.03	−1.45	3.51
Riding toys (N = 565)	−0.85	−2.15	0.44	1.29	−0.15	2.74
Sticks (N = 579)	**2.16**	**0.38**	**3.94**	1.23	−1.31	3.77
Gym mats (N = 584)	**2.08**	**0.57**	**3.59**	1.94	−0.35	4.22
Parachute (N = 584)	−0.59	−1.72	0.54	−0.55	−2.63	1.54
Bean bags (N = 562)	0.81	−1.88	3.51	**2.58**	**0.23**	**4.94**
Exercise balls (N = 570)	0.98	−0.47	2.43	0.10	−1.34	1.55
Trampoline (N = 584)	0.54	−1.35	2.42	0.23	−1.54	1.99
Crawling tunnel (N = 573)	1.61	−0.08	3.31	0.73	−1.24	2.70
Hoops (N = 584)	−1.08	−2.85	0.69	1.19	−0.47	2.85
Movable floor markers (N = 568)	−0.97	−2.06	0.11	−0.11	−1.61	1.39
Hopper balls (N = 574)	0.65	−0.74	2.04	1.17	−0.39	2.72
Game equipment (N = 571)	0.47	−1.48	2.43	1.52	−0.37	3.41
Total amount of PA equipment in the gym (N = 503)	0.37	−0.18	0.91	0.44	−0.08	0.95
Total amount of equipment in group facilities, fixed equipment indoors and equipment in the gym (N = 778)	0.11	−0.04	0.26	0.01	−0.11	0.11
Surfaces in the preschool ground						
Asphalt (N = 770)	0.86	−0.39	2.12	0.11	−1.16	1.38
Grass (N = 770)	0.31	−0.84	1.46	−1.25	−2.82	0.32
Gravel (N = 770)	**−1.87**	**−3.38**	**−0.36**	0.90	−0.54	2.34
Sand (N = 770)	**1.66**	**0.23**	**3.09**	−1.33	−3.34	0.69
Safety surfacing (N = 770)	0.87	−0.19	1.89	0.11	−1.48	1.71
Rocks (N = 770)	0.01	−1.21	1.24	−0.33	−1.76	1.10
Forest (N = 770)	−0.59	−1.87	0.69	0.66	−1.36	2.68
Trees (N = 770)	−0.34	−2.13	1.45	0.59	−0.84	2.02
Tiling (N = 751)	0.80	−0.47	2.08	0.89	−0.36	2.13
Terrain on the playground						
Mostly flat (N = 770)	−0.69	−1.81	0.42	0.71	−0.61	2.02
Mostly hilly (N = 770)	**2.07**	**0.91**	**3.23**	−0.17	−1.51	1.17
Combination of both (N = 770)	0.36	−0.83	1.56	−0.38	−1.69	0.94
Shady areas on the playground						
At the sides (N = 770)	0.04	−1.43	1.51	0.63	−0.97	2.23
In play areas (N = 770)	−0.93	−2.26	0.40	−0.22	−1.51	1.07
No shade (N = 770)	−0.19	−2.12	1.73	0.75	−1.22	2.71
PA promoting elements in the playground						
Soccer field (N = 768)	0.04	−1.23	1.31	0.11	−1.48	1.70
Ball wall (N = 768)	−0.63	−1.75	0.49	0.58	−0.76	1.92
Basketball hoop (N = 763)	−0.53	−1.95	0.89	0.83	−0.52	2.18
Track area for riding toys (N = 743)	−0.42	−1.54	0.70	0.68	−0.72	2.08
Outdoor play paintings on the ground (N = 778)	0.15	−1.41	1.70	−0.62	−2.38	1.14

Table 3 (*Continued*)

	Total PA min/hour					
	Main effects[a]			Moderator effects[b]		
	β	Lower 95% CI	Upper 95% CI	β	Lower 95% CI	Upper 95% CI
Fixed PA equipment in the preschool yard						
Playhouse (N = 763)	−0.88	−2.22	0.46	−0.24	−1.59	1.11
Spring swings (N = 765)	0.56	−0.98	2.11	1.02	−0.57	2.61
Seesaw (N = 778)	**−1.63**	**−2.63**	**−0.63**	−0.58	−1.91	0.74
Climbing frames (N = 778)	0.23	−1.86	2.32	0.36	−2.30	3.01
Slides (N = 765)	0.71	−0.77	2.19	**−2.46**	**−4.29**	**−0.62**
Balancing equipment (N = 756)	−0.83	−2.10	0.43	−0.53	−1.91	0.85
Merry-go-rounds (N = 730)	−0.82	−2.16	0.53	−0.48	−1.99	1.03
Total amount of fixed equipment in the preschool yard (N = 778)	−0.35	−0.71	0.01	−0.14	−0.56	0.31
Portable PA equipment in the playground						
Balls (N = 765)	0.88	−3.56	5.33	−0.04	−4.89	4.81
Skipping ropes (N = 778)	**1.59**	**0.24**	**2.94**	0.82	−0.60	2.24
Balance equipment (N = 778)	1.60	−0.13	3.33	0.68	−1.20	2.55
Riding toys (N = 766)	−0.91	−4.01	2.19	−0.60	−7.46	6.23
Sticks (N = 761)	1.18	−0.47	2.84	−0.53	−2.62	1.55
Goals (N = 766)	−0.38	−1.73	0.97	0.27	−1.23	1.77
Sleds (N = 737)	−0.41	−2.38	1.53	−0.25	−3.73	3.24
Snow pushers (N = 749)	−1.19	−2.43	0.06	−1.17	−2.50	0.17
Total amount of portable equipment in the playground (N = 778)	0.17	−0.22	0.56	0.03	−0.44	0.50
Total amount of fixed and portable equipment in the preschool yard (N = 778)	−0.07	−0.31	0.17	−0.01	−0.30	0.28

[a] Associations between each independent variable and the dependent variable adjusted for child's age and gender, municipality, and season of measurement and clustered with preschool group.

[b] Moderator effects: interactions between independent variable and child's gender (boy = 1, girl = 0) adjusted for child's age and gender, municipality, season of measurement and clustered with preschool group.

[c] Associations between each independent variable and the dependent variable adjusted for child's age and gender, season of measurement and clustered with preschool group and moderator effects: interactions between independent variable and child's gender (boy = 1, girl = 0) adjusted for child's age and gender, season of measurement and clustered with preschool group.

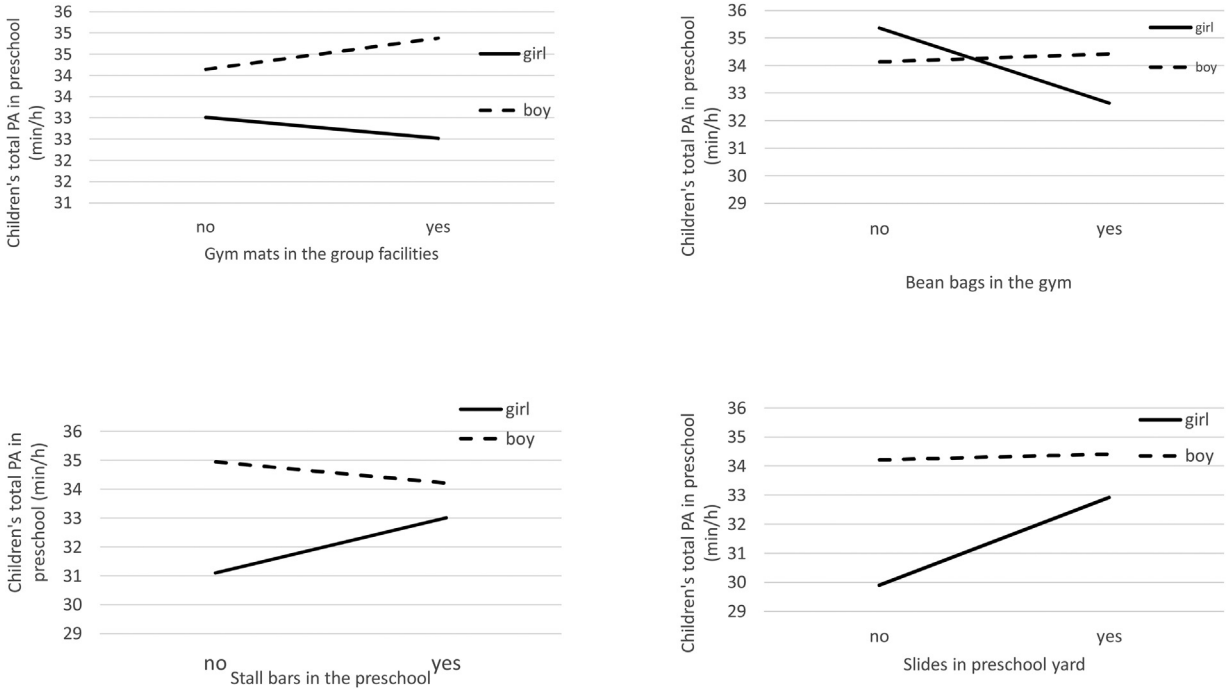

Fig. 1. Associations between gym mats in the preschool's group facilities, stall bars, bean bags in the gym and slides and children's physical activity (PA, min/h) among girls and boys.

may also be valuable when deciding on the availability of equipment in preschools. The availability of multiple types of equipment may be especially relevant in the Finnish-type preschool context, where children have multiple daily free playing times and therefore several options to choose for their activity.

Our study found that predominantly hilly terrain in the preschool grounds was associated with higher PA. This finding replicates that of a Danish study, which also found that higher PA was associated with a hilly landscape in the preschool yard (Olesen et al., 2013). Many other studies have demonstrated the association between higher PA and having an open area suitable for active play. However, we were unable to include open outdoor space in our final analysis, due to the non-variation in our study sample. Nonetheless, predominantly hilly terrain in the preschool yard may provide similar possibilities for children to be active as open areas. Spacious, hilly environments may inspire children to run, jump and freely engage in 'risky play' (Sandseter & Kennair, 2011), thereby resulting in greater movement. In contrast to other studies (Cardon et al., 2008; Nicaise, Kahan, & Sallis, 2011; Sugiyama, Okely, Masters, & Moore, 2012), hard surfaces in the playground were not associated with children's PA in our study. Instead, sand was associated with higher PA, whereas gravel was associated with lower PA. Another study has suggested that the association between sand and higher PA is due to children's preference for playgrounds with a softer surface (Nasar & Holloman, 2013). This, in turn, may be because playing in softer materials is easier and because children have less fear of injury. By contrast, gravel may be hard and uncomfortable to play with. When planning future locations for preschools, it is important to ensure that preschool yards provide a variety of natural terrains with height differences and soft surfaces.

Although there were no significant associations between these variables and children's PA once the sample was stratified by gender, the results suggest that fixed equipment such as slides and stall bars are associated with higher levels of PA in girls. This finding is especially important given that some studies have reported that girls are less active than boys (Bingham et al., 2016; Hesketh et al., 2016). Although our sample size was larger than that of many other studies among preschool children (Tonge et al., 2016), further research with even larger sample sizes is needed for a more in-depth investigation of the interaction between gender and PA.

A limitation of this study is the low participation rate of the children (27%), which may influence on the generalizability of our findings. Many preschools had a wide range of available PA equipment, thereby limiting the variation in equipment levels in our sample and preventing us from testing some potential associations. Furthermore, inter-observer reliability of the observations was not assessed. Although it was based on validated observation instruments, our observation form itself was not validated.

Several accelerometer cut-points exist for measuring preschool children's PA, and using other cut-points might have produced different results. Additionally, outdoor times and indoor times were not separated in our accelerometer data. It is not possible to know whether selection bias occurred, and the most active children participated. We acknowledge that other factors, such as social interaction between early educators, and policy regulations, can affect children's PA. Future research could therefore study the interaction between the physical, social and policy environments of preschool and their associations with children's PA.

6. Conclusions

This study furthered understanding of the associations between children's PA and various physical environmental factors in a preschool setting, by using objective measurements and direct observations instead of less valid measures, such as self-report. Due to a quite high participation rate of preschools (56%), we were able to observe many kinds of preschool settings in a variety of physical environments and regions of the country. This allowed us to study the availability of equipment and the natural environment in several places and ensured the heterogeneity of the preschools studied. Our main findings indicate that having equipment related to jumping or balancing skills, having predominantly hilly terrain in the preschool grounds and having sand as a surface were associated with higher PA. By contrast, seesaws and having gravel as an outdoor surface were associated with lower PA levels.

These results are important for preschool organizations and for municipal technical and planning services when designing the ideal physical environment for promoting children's PA. A variety of equipment in different contexts (e.g. group facilities, outdoors) and a diversity of natural surfaces in the preschool grounds may be essential.

Declarations of interest

None.

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