New physical activity spaces in deprived neighborhoods: Does it change outdoor play and sedentary behavior? A natural experiment

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ABSTRACT

Background: We used the introduction of dedicated physical activity (PA) spaces in Rotterdam, the Netherlands, to study the impact of reducing distance to dedicated PA spaces on outdoor play and sedentary behavior, and to evaluate if these effects were similar between population subgroups.

Methods: We included 1841 Dutch children from the Generation R Study who participated at two subsequent measurement waves when the children were, on average, 6.0 and 9.7 years old. None of these children lived within 600 m of a dedicated PA space at baseline, and during follow-up 171 children became exposed to 13 new PA spaces within 600 m from home. Individual-level fixed-effects models were used to evaluate changes in distances (determined by Geographical Information Systems (GIS)) from home to the nearest new dedicated PA space, to parent-reported outdoor play and sedentary behavior.

Results: The introduction of a dedicated PA space within 600 m from home, and the reduction of the distance per 100 m, did not affect outdoor play or sedentary behaviors. At $p < 0.1$, significant interaction terms were found between the introduction of the PA spaces and indicators of family socioeconomic position. Although not statistically significant, stratified analyses showed a consistent pattern, suggesting that reducing the distance to the nearest PA space increased outdoor play for children from parents with lower levels of education. However, they also showed a non-significant increase in sedentary behaviors for children from families with net household income below average Dutch income, and for children from a non-Dutch ethnicity.

Conclusions: Introducing dedicated PA spaces may be a promising approach to increase outdoor play for children from more socioeconomically disadvantaged families, but larger studies are needed to contribute to the evidence.

1. Background

Promoting physical activity at young ages is a key strategy to combat childhood obesity (Lobstein et al., 2004; Ebbeling et al., 2002; World Health Organization, 2012). A supportive neighborhood with access to physical activity (PA) spaces is considered to be important for this purpose. However, there is little robust evidence on the causal relationship between changes in the built environment and physical activity behavior (Committee on Environmental Health, 2009; Ding et al., 2011; Timperio et al., 2015). Most studies have relied on cross-sectional data, leaving the question unanswered whether higher access to PA spaces make children living in neighborhoods more physically active, or whether parents who would like their children to engage in

physical activity reside in neighborhoods with better opportunities to do so.

Randomized controlled trials (RCTs) are the gold-standard to demonstrate causality, but it is difficult or perhaps even impossible to randomly assign play facilities. So-called "natural experiments" provide an alternative for situations in which the researcher lacks control over the intervention, but where the variation in access to play facilities can be used to allocate an intervention and control status to individuals (Craig et al., 2012). Due to the non-random introduction of PA spaces – presumably there where the need is largest – children who will and will not live closer to PA spaces after the follow up period, may differ in many ways. However, as long as the change in physical activity behaviors within a child is independent from factors associated with the

introduction of PA spaces, the introduction of PA spaces can be seen as an "exogenous" intervention. To the extent that time-invariant factors determine the introduction of PA spaces and the change in physical activity, fixed-effects analyses control for such (unobserved) confounding.

In the past years, two foundations established by Dutch sports legends (Richard Krajicek, former professional tennis player, Wimbledon champion; Johan Cruyff, former professional football player and coach) introduced new PA spaces in Dutch cities to encourage physical activity at young ages, with a special focus on children living in deprived neighborhoods. The introduction of 18 dedicated PA spaces in the city of Rotterdam, the Netherlands, provides the unique opportunity to evaluate the impact of a changing built environment on health behavior. Specifically, this study aimed to investigate the impact of the introduction of dedicated PA spaces on outdoor play and sedentary behavior of children. The PA spaces specifically target deprived neighborhoods; our secondary aim therefore was to evaluate whether the observed effects vary by family household income, parental education level, and ethnicity.

2. Methods

2.1. Study design

We evaluated the introduction of 18 PA spaces between February 2008 and December 2015, using data from the Generation R prospective birth-cohort study (Kooijman et al., 2016). The timeline of the intervention and data collection is presented in Fig. 1.

2.2. The intervention: 18 new physical activity spaces in Rotterdam

In most cases the local government in Rotterdam applied for a dedicated PA space, but in exceptional cases (approximately 1 out of 10) residents initiated the application procedure. The applications are considered by the foundations on predefined criteria. Neighborhoods that are eligible for a PA space are deprived, have low physical activity levels or sport participation rates among youth, or can otherwise show that the introduction of PA spaces is likely to be of benefit for children's development. Neighborhood support is essential, and local residents are involved in the decision-making process about, for example, the design, location and the activities hosted on the new PA space. The local government is responsible for providing the additional funds needed for the introduction and maintenance of the facilities.

An impression of the PA spaces is given in Supplemental Fig. 1. The PA spaces have many similarities, and target children aged 6–18 years. Although the design of the multifunctional PA spaces is tailored to the needs of the specific location, specific features like goals, colorful markings, and fences are present at most locations. PA spaces included a soccer field, basketball court, tennis field, playground equipment, or a combination here off. Some PA spaces additionally contained a mini-athletics track, panna-court, tennis table, skating rink, fitness items, volleyball field, or dance floor. All PA spaces are freely accessible, centrally located in the neighborhood, often supervised during peak usage hours, and regularly host sports activities. The first Krajicek Playground in Rotterdam, the Netherlands, was opened in 2001; the first Cruyff Court in 2005.

2.3. Study population

Data from the Generation R Study, a population-based, prospective birth cohort study were used to evaluate the introduction of the PA spaces. Invitations to participate in the Generation R Study were sent out to all pregnant women who had an expected delivery date between April 2002 and January 2006 and who lived in the study area (Rotterdam, the Netherlands) at time of delivery. More information is presented in the design and cohort update paper (Kooijman et al., 2016). The Medical Ethics Committee of the Erasmus University Medical Center in Rotterdam approved the study. Written informed consent
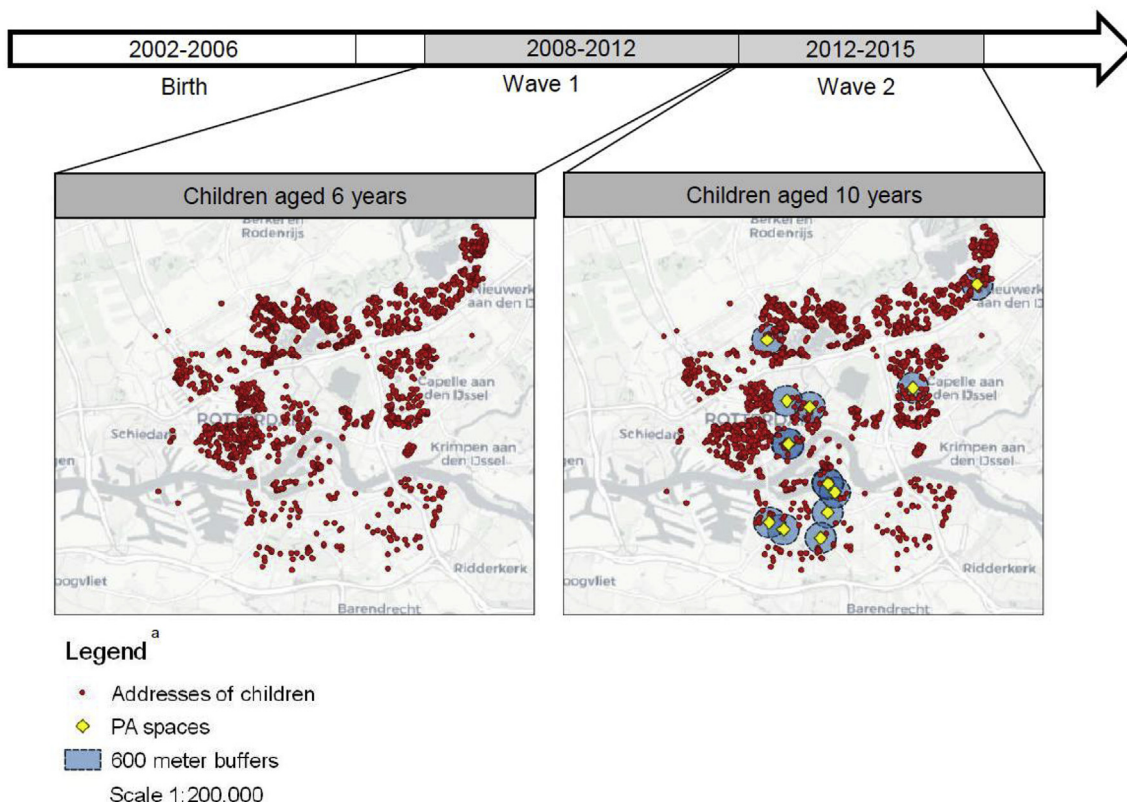

Fig. 1. Timeline of the natural experiment [a] The map was derived from OpenMapTiles (http://openmaptiles.org/).

was obtained from all participants.

For this study, we included children who participated in two subsequent measurement waves when the children were on average 6.0 years old (February 2008 to January 2012) and 9.7 years old (February 2012 to December 2015) (n = 7254). Two questionnaires were returned by 4886 parents (67%). At each measurement wave we excluded children that no longer lived in Rotterdam (n = 1485), children with a missing or invalid residential address (n = 137), children without repeated measures for outdoor play or sedentary behavior (n = 589), outliers with unrealistic levels of outdoor play > 5 h/day (n = 51), and children without any information about time-varying net household income (n = 85), sport participation (n = 15), or active transport to school (n = 16). Furthermore, we excluded children that moved houses during follow-up (n = 333), to avoid selective migration. Clustering could occur within families, therefore we excluded younger siblings from the same mother (n = 211).

Following recent recommendations to use observational data for an evaluation as if it was a trial (Hernán and Robins, 2016), we excluded children that were exposed to dedicated PA spaces at baseline within 600 m of their home (n = 442). The population of analyses included 1841 children without access to PA spaces. Due to different numbers of missing outcome variables, the population of analyses were different for outdoor play (n = 1607) and sedentary behavior (n = 1545).

2.4. Distance to PA spaces using buffers

Information about the location of the PA spaces was obtained from the Krajicek and Cruyff foundations. The software QGIS was used to create Euclidian buffers of 600 m around children's homes. Commonly used street network distances are not available in the Generation R Study. Yet, the city planning of the Netherlands is characterized by an extremely high connectivity, including small alleys only accessible by feet or bike, perfectly suitable for children. In this context it is reasonable to assume that measurement error in the exposure induced by Euclidean distances is minimal. At both periods of measurement, the presence of existing and new dedicated PA spaces within buffers was determined, and this allowed us to distinguish the intervention group (no PA space in wave 1, a PA space in wave 2) from the control group (PA space absent at both waves). There is no information available about the actual distance Dutch children walk or cycle to visit a PA space. The buffer size of 600 m was chosen based on the mean radius of a Rotterdam neighborhood in 2008 (Statistics Netherlands, 2004). Importantly, the distance to PA spaces differ per individual, and are unrelated to neighborhood borders. Children in the intervention group lived in 19 neighborhoods. In 18 of these neighborhoods some children were included in the intervention group, while other children from the same neighborhood were included in the control group. It illustrates the often echoed critique on using neighborhood boundaries, which have little meaning for children when it comes to access to facilities.

2.5. Distance to PA spaces using a continuous measure

The effects on playing outdoors are presumably small if children still live far away after the introduction of new play facilities. Indeed, 200 m closer to a facility might matter more for those who originally lived 600 m from a facility instead of for example 1600 m from the nearest dedicated PA space. In a separate analysis, we truncated all distances above 600 m to 600 m (resulting in "no change in distance" for those who never lived within 600 m) and investigated the impact of the absolute change in distance living closer to a PA space within the 600 m buffer.

2.6. Outdoor play and sedentary behavior

Outdoor play and sedentary behavior were assessed by parent-reports. Outdoor play concerned exercise at school and outside school

hours for an average week. At the age of 6 years, frequency (number of days) and duration (never, less than 30 min, 30–60 min, 1–2 h, 2–3 h, 3–4 h) were asked for weekdays and weekend days separately. The midpoint of each category (e.g. 45 min for 30–60 min) was used to estimate the duration of a session. The frequency was multiplied by duration, and estimates for weekdays and weekend days were summed to obtain the average time spent playing outdoors in minutes per week at the age of 6 years. The same procedure was used at the age of 10 years, although answer options for frequency and duration slightly differed, and did not specify for weekdays and weekend days. Appendix 2 includes the questionnaires and coding.

Sedentary behavior was assessed through two separate questions on television viewing and computer game use for an average week. Questions included frequency and duration, for weekdays and weekend days separately. Again, the frequency was multiplied by the duration to calculate the average time spent television viewing and computer gaming. Time spent television viewing and computer gaming was summed to obtain the average time spent engaging in sedentary behaviors in minutes per week at the age of 6 and 10 years.

2.7. Physical activity behaviors

Other physical activity behaviors assessed by parent-reports at age 6 and 10 included the number of sport activities in which a child participated, and the number of days that children walked or cycled to school.

2.8. Socio-demographic variables

Parent self-reported highest obtained maternal and paternal education level at the child's age of 6 years were categorized according to the Dutch Standard Classification of Education into high (university degree), mid-high (higher vocational training, bachelor's degree), mid-low (> 3 years general secondary school, intermediate vocational training), and low (no education, primary school, lower vocational training, intermediate general school, or ≤3 years general secondary school) (Statistics Netherlands, 2003). Information about maternal and paternal employment status (paid job, no paid job) was collected when the child was 6 years, whereas net household income (≤€2000/month, < €2000-€3200/month, > €3200/month) was collected at both time points. In accordance with Statistics Netherlands, a child's ethnic background was classified as native Dutch, other-Western background (countries in Europe, North-America and Oceania), and non-Western background (countries in Africa, Latin-America and Asia, including Turkey) based on the country of birth of the child's parents (Statistics Netherlands, 2010).

2.9. Statistical analyses

Baseline characteristics of the study population were presented as means with standard deviations (SDs) for normally distributed variables, medians with inter quartile range (IQR) for skewed variables, and percentages for categorical variables.

First, multi-variable linear regression models were constructed to evaluate the cross-sectional association between exposure to a PA space within 600 m from home and outdoor play and sedentary behaviors at the age of 10 years. Subsequently, fixed-effects regression models were applied, which allow to control for measured time-variant and for unmeasured time-invariant confounders (Allison, 1994, 2009; Cousens et al., 2011). As time-varying confounders, net household income, season of data collection, sport participation, and active transport to school were controlled for. If net household income, sport participation or active transport to school was missing at age 6, the value measured at age 10 was imputed (n = 73 for income; n = 32 for sport participation; n = 69 for active transport to school), and *vice versa* (n = 67 for income; n = 25 for sport participation; n = 13 for active transport to

school). The following regression model was used:

$$y_{it} = \alpha_t + \beta_1 (intervention_{it}) + \beta_2 (x_{it}) + \mu_i + \varepsilon_{it}$$

where y_{it} is the dependent variable of interest (e.g. outdoor play and sedentary behavior) for individual i at time t, β_1 is the effect of the intervention for individual i on time t, β_2 is the effect of time-varying factors for individual i on time t, α_t accounts for time effects that are constant across individuals, μ_i accounts for time-invariant random errors on the individual-level, and ε_{it} accounts for normal sources of error that vary across individuals and time.

Five sensitivity analyses were conducted. First, we repeated the analyses using buffers of 400 and 800 m to explore if larger effects were found for children living closer to the nearest PA space thereby receiving the highest exposure. Second, we included children who moved houses during follow-up, to evaluate if selective migration took place. Third, we excluded children for which the data were collected within 6 months after introduction of the new facility, to account for the novelty effect and assure that long term impact is obtained. Fourth, we used the median exposure time (the time between opening of the PA space and second measurement; 1.9 years) to stratify the sample into lower and higher exposure time, and assessed if this would influence the change in physical activity behaviors. Fifth, to be able to compare outcomes in the same group of children, we excluded children with missing data.

The dedicated PA spaces specifically target deprived neighborhoods, which host relatively more persons from lower socioeconomic and ethnic minority groups. Interaction terms were introduced to assess a differential impact of new PA spaces for the intervention and control group by maternal and paternal education level, net household income and ethnicity. To retain statistical power, parental education level was dichotomized into higher (high, mid-high) and lower education level (mid-low, low). Likewise, net household income was dichotomized into higher (> €3200/month) and lower than average Dutch net household income (≤€3200/month). All analyses were conducted in R version 3.4.1, using the plm package for the fixed-effects analyses. Clustered sandwich estimators were used to allow for within-child correlation between error terms. Two-sided P-values < 0.05 were considered statistically significant. Interactions were explored for P-for-interactions < 0.10.

3. Results

The intervention group consisted of 171 children who gained access to dedicated PA spaces within 600 m of their home during follow-up. The children in the intervention group were more often of non-Western ethnicity, less often participated in sports, played ~1 h/week more outdoors, and were more often from families with lower parental education level and lower net household income, as compared to children in the control group (Table 1). Children in the intervention group were exposed to 13 different PA spaces with, on average, 13 children (range: 1–55) being exposed per PA space.

Cross-sectional analyses at the age of 10 years showed that children in the intervention group played 40 min/week (95% CI: −6, 87) more outside as compared to children in the control group (Supplemental Table 1). For children from families with lower maternal education level, outdoor play was 96 min/week (95% CI: 18, 174) higher as compared to children in the control group. The difference in sedentary behavior was 78 min/week (95% CI: −23, 179), and 101 min/week (95% CI: −86, 288), respectively.

3.1. Buffers to assign exposure

The introduction of a dedicated PA space within 600 m from home between the age of 6 and 10 years had no effect on outdoor play (−25 min/week (95% CI: −101, 51 min/week)) or sedentary behaviors (55 min/week (95% CI: −57, 167 min/week)), when controlling for the average decline in outdoor play, and increase in sedentary

behaviors in the population (Table 2). The time-varying factors in the model showed that outdoor play was lower during autumn and winter, but did not differ by income, sport participation, or active transport to school. Sedentary behaviors was not determined by any of the time-varying factors.

3.2. Absolute distance to assign exposure

Findings were similar when using distance as continuous variable instead of dichotomous buffer size. Decreasing the distance to a dedicated PA space by 100 m had no effect on outdoor play (−3 min/week (95% CI: −31, 25 min/week)), or sedentary behaviors (42 min/week (95% CI: −16, 99 min/week)) (Table 2).

3.3. Sensitivity analyses

Using alternative buffer sizes, including children who moved houses, excluding children for which data was collected within 6 months after opening of a PA space, stratifying the analyses for children with lower and higher exposure time, and excluding children that had only data for outdoor play or sedentary behaviors, yielded essentially similar results (Supplemental Table 2).

3.4. Subgroup analyses

Stratified analyses were performed for all indicators of family socioeconomic position that were considered significant (P-for-interaction < 0.10). Although estimates for each stratum did not reach statistical significance, a consistent pattern was found, suggesting that reducing the distance to the nearest PA space increased outdoor play for children from families with lower maternal or paternal education level (Fig. 2; Supplemental Table 3). However, they also showed a non-significant increase in sedentary behaviors for children from families with net household income below average Dutch income, and for children from a non-Dutch ethnicity (Fig. 2; Supplemental Table 4).

3.5. Children from socioeconomically disadvantaged families

We explored if larger effects were found when using smaller buffer sizes for children from families with lower maternal education level. New PA spaces within 400 m of home increased outdoor play non-significantly by 78 min/week (95% CI: −70, 226 min/week), within 600 m by 45 min/week (95% CI: −72, 163 min/week), and within 800 m by 25 min/week (95% CI: −86, 137 min/week) (Supplemental Table 5). To the contrary, no such exposure-response relationship was found for sedentary behaviors.

4. Discussion

Children in the intervention group were more often from socioeconomically disadvantaged families, and had higher baseline levels of outdoor play, as compared to children in the control group. We found that the introduction of dedicated PA spaces within 600 m of home in deprived areas in Rotterdam did not affect changes in outdoor play or sedentary behaviors between the age of 6 and 10 years. Although not statistically significant, stratified analyses suggested that the change in outdoor play was largest for children with parental education level up to 3 years general secondary school, or with intermediate vocational training. We also found that living closer to PA spaces non-significantly increased sedentary behaviors for children from families with net household income up to €3200/month (close to average net household income in the Netherlands), and for children from a non-Dutch ethnicity.

Table 1

Characteristics of the study population (n = 1841) at age 6 (2008–2012) and 10 (2012–2015).

	Age 6		P-value[a]	Age 10		P-value
	Intervention group	Control group		Intervention group	Control group	
	(n = 171)	(n = 1670)		(n = 171)	(n = 1670)	
Child characteristics						
Age, years	6.0 ± 0.4[b]	6.0 ± 0.4	0.86	9.7 ± 0.2	9.7 ± 0.3	0.040
Sex, n (%)			0.10			
Girls	96 (56.1)	822 (49.2)				
Boys	75 (43.9)	848 (50.8)				
Ethnic background, n (%)			0.017			
Dutch	103 (60.2)	1164 (69.7)				
Other-Western	22 (12.9)	200 (12.0)				
Non-Western	46 (26.9)	305 (18.3)				
Sport participation, n (%)[c]			0.088			0.68
No sport	103 (61.7)	857 (52.2)		19 (11.2)	169 (10.3)	
1 sport	54 (32.3)	643 (39.2)		94 (55.3)	848 (51.5)	
2 sports	10 (6.0)	127 (7.7)		47 (27.6)	528 (32.1)	
3 sports	0 (0.0)	15 (0.9)		10 (5.9)	101 (6.1)	
Outdoor play, min/week	693 ± 461	624 ± 418	0.051	404 ± 332	379 ± 320	0.34
Sedentary behavior, min/week	699 ± 443	660 ± 487	0.35	1107 ± 763	1024 ± 689	0.16
Active transport to school, days/week[c]	3 (1–5)[d]	4 (1–5)	0.067	5 (4–5)	5 (4–5)	0.030
Family characteristics						
Maternal education level, n (%)			0.020			
High	39 (23.1)	576 (34.7)				
Mid-High	52 (30.8)	465 (28.0)				
Mid-Low	61 (36.1)	475 (28.6)				
Low	17 (10.1)	142 (8.6)				
Paternal education level, n (%)			0.006			
High	40 (24.8)	595 (38.5)				
Mid-High	47 (29.2)	370 (23.9)				
Mid-Low	48 (29.8)	406 (26.3)				
Low	26 (16.1)	175 (11.3)				
Maternal employment status, n (%)			0.73			
Paid job	130 (82.3)	1297 (80.8)				
No paid job	28 (17.7)	308 (19.2)				
Paternal employment status, n (%)			0.44			
Paid job	152 (95.0)	1454 (93.0)				
No paid job	8 (5.0)	109 (7.0)				
Net household income, n (%)[c]			0.048			0.39
≤€2000/month	29 (17.5)	247 (15.4)		32 (19.5)	251 (15.7)	
>€2000-€3200/month	57 (34.3)	428 (26.7)		38 (23.2)	359 (22.4)	
>€3200/month	80 (48.2)	927 (57.9)		94 (57.3)	991 (61.9)	

[a] P-values for differences between intervention and control group were obtained from ANOVA (normally distributed continuous variables), Kruskal-Wallis test (skewed continuous variables), or Chi-square test (categorical variables).
[b] Mean ± SD (all such values).
[c] Not-imputed values.
[d] Median; IQR in parentheses (all such values).

Table 2

The effect of the introduction of PA spaces on changes in outdoor play and sedentary behavior.

Intervention/control (n)	Outdoor play (min/week, 95% CI)		Sedentary behavior (min/week, 95% CI)	
	(152/1455)		(133/1412)	
	Buffer < 600 m	Per 100 m	Buffer < 600 m	Per 100 m
Exposure to PA spaces	−25 (−101, 51)	−3 (−31, 25)	55 (−57, 167)	42 (−16, 99)
Time	−211 (−241, −181)	−213 (−242, −183)	394 (353, 434)	392 (352, 432)
Net household income				
≤€2000/month	–	–	–	–
>€2000-€3200/month	41 (−37, 120)	41 (−37, 120)	−75 (−187, 37)	−78 (−190, 35)
>€3200/month	63 (−27, 153)	63 (−27, 153)	−83 (−211, 44)	−87 (−215, 41)
Season of data collection				
Spring	–	–	–	–
Summer	29 (−13, 72)	29 (−13, 71)	−24 (−82, 35)	−24 (−82, 35)
Autumn	−154 (−197, −111)	−155 (−198, −112)	−54 (−114, 5)	−55 (−114, 5)
Winter	−252 (−293, −212)	−253 (−294, −212)	39 (−17, 96)	39 (−18, 96)
Active transport to school (days/week)	−5 (−16, 5)	−5 (−16, 5)	−4 (−19, 11)	−4 (−19, 11)
Sport participation (number of sports)	−22 (−47, 2)	−23 (−47, 2)	−26 (−59, 7)	−27 (−60, 6)

Values (95% confidence intervals) indicate changes in outdoor play time or sedentary behavior time (in minutes per week) for children who were living closer to the nearest dedicated PA space, as compared to children without changes in distance.
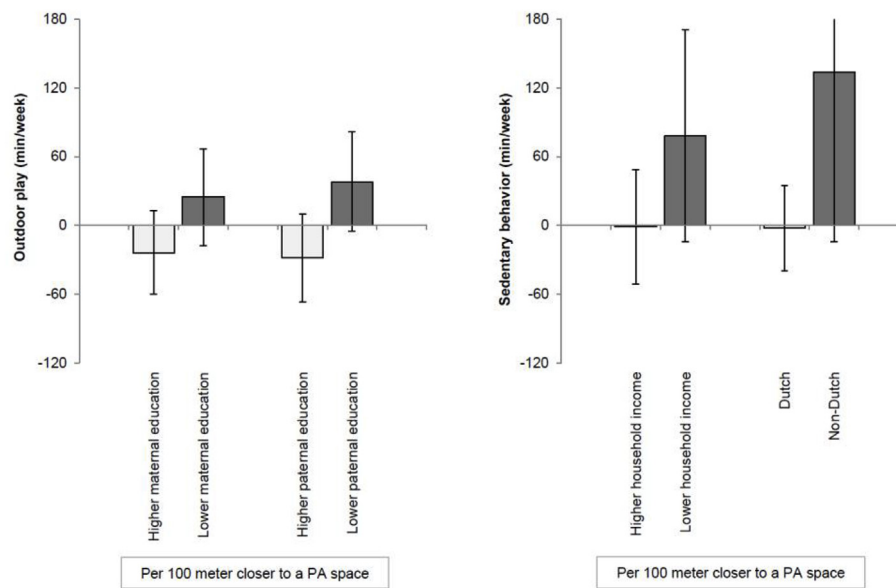
Fig. 2. The effect of the introduction of PA spaces on changes in physical activity behaviors, stratified by indicators of family socioeconomic position.

4.1. Strength and limitations

Our study has several strengths. First, this study was strengthened by using a study design and selecting a population that closely mimics the situation that would have been appropriate if the study was conducted in an experimental setting, as recently proposed by Hernán et al. (Hernán and Robins, 2016). Consequently, we only included children that did not live close to a PA space at baseline, and estimated the effect of the introduction of new facilities on physical activity behaviors within a group of children that did not move houses. The association between the intervention and outcomes reported in this study approximate the effect estimates that would have been obtained if randomization procedures would have allocated intervention and control status to children.

Second, the latter is strengthened by our fixed-effects analysis. Previously reported associations between outdoor play facilities and physical activity may be confounded. Perhaps most prominently, parental attitudes towards children's health may both determine living at a place where children can play outside and their physical activity behavior. Clearly, even though we were able to control for such unobserved time-invariant confounding, time-variant factors may cause confounding (as it does using other methods).

Third, our measure of exposure was determined at the individual-level. Some children were allocated to the intervention group, while others living in the same neighborhood were allocated to the control group. Despite the fact that the intervention was implemented in neighborhoods, random-effect multilevel models seemed less appropriate; we do not expect a clustering of outcomes within neighborhoods.

The main limitation of this study is the lack of power. In order to detect a 1 h/week (SD: 7) difference in outdoor play between the intervention and control group with a power of 0.80, we would have needed around 400 children in each group. When conceptualizing the study, we were confident that we could include a sufficient number of children in the intervention group. During the study period, 18 dedicated PA spaces were built spread across the city. A 4-year difference between the first and second measure of physical activity behaviors seemed to be sufficiently large for children to experience a change in distance to the nearest dedicated PA space, but small enough to be able to attribute the change in outdoor play to the intervention. Unfortunately, we had to exclude nearly a fifth of the study population that were already living within 600 m of a PA space at baseline, and the

number of children being exposed to a new PA space during follow-up was much smaller than expected.

Another major limitation is that we had no GPS measurements available, and therefore could not identify whether children's physical activity occurred at the PA spaces. The finding of larger effect sizes when using smaller buffers in the group which seemed to be most responsive to the intervention provides some support that the impact of PA spaces was measured. Spatial and temporal certainty is needed to strengthen the evidence of built environment interventions (Dunton et al., 2014; Humphreys et al., 2016). We had to rely on parent reports, which may be prone to recall and social desirability biases, and did not allow to assess the level of physical activity intensity. For 93% of the children the same parent filled in the questionnaire twice, thereby offsetting some of the biases that may have occurred if different parents filled in the questionnaire. Similarly, the answer categories slightly changed over time. The questionnaire used at the age of 6 years better captured outdoor play for children that played frequently outside. We excluded children with unrealistic high levels of outdoor play, nevertheless, the major decline in outdoor play time may have been partly resulted from the change in questionnaire items. However, when evaluating the introduction of PA spaces, this is less of a problem since only small differences were seen in time spent playing outdoors at baseline between intervention and control group. The variety of activities that can be performed at the PA spaces, and the density of physical activity programs, may be of importance to stimulate behavioral change. Power issues, and incomplete information on the programming on the fields, did not allow to further explore this.

Children in the intervention group spent more time playing outdoors at baseline, and stratified analyses on baseline levels of outdoor play showed that children with low levels of outdoor play had largest increase in the time spent playing outdoors (results not shown). This may have resulted from the statistical phenomena regression to the mean, whereby children with extreme levels during the first measurement round fall back to the mean when measured a second time. Another explanation for the increase in outdoor play is that children with low baseline levels of physical activity are more responsive to the intervention. The effect found in the mid-tertile was not essentially different from the results in the main analyses. Careful examination of baseline characteristics is warranted when evaluating absolute changes over time using fixed-effects models.

When analyzed in a cross-sectional way, we found that children at the age of 10 years with a PA space nearby played 0.5 h/week more

outside as compared to children without dedicated PA spaces around home. For children from families with lower maternal education level, outdoor play was 1.5 h/week higher. These estimates are larger then found in the (natural) experimental setting, suggesting that both selection and causation mechanisms may explain the relationship between access to play facilities and physical activity.

An earlier study showed that Krajicek playgrounds attract more children and that their physical activity intensity is higher compared to children playing at regular PA spaces (Boonzajer Flaes et al., 2016). Although not statistically significant, our study suggested some increase in time spent playing outdoors for children from more disadvantaged families, thus outdoor play did not shift only from other locations to dedicated PA spaces. Playing more outside at higher intensities could have a beneficial impact on children's health (Ekelund et al., 2012).

We found some evidence that sedentary behaviors increased following the introduction of PA spaces. A meta-analyses also showed that an increase physical activity does not necessarily reduce sedentary behaviors (Pearson et al., 2014). A possible explanation is that children compensate their physical activity and sedentary behaviors between days (Rowland, 1998; Frémeaux et al., 2011; Ridgers et al., 2014). Thus, being active at one time will result in a decrease in physical activity and an increase in sedentary behaviors at another time. For example, compensation occurs when parents reward their children for playing outside by allowing screen time. Further research is needed to examine the potential compensation mechanisms following interventions to promote physical activity behaviors.

The introduction of dedicated PA spaces was confined to deprived neighborhoods, however, the absolute level of deprivation varied across neighborhoods. Previous work described Dutch deprived neighborhoods as neighborhoods "(…) with problems regarding employment, education, housing and the physical neighborhood environment, social cohesion, and safety" (Droomers et al., 2014). For the city of Rotterdam it was estimated that life expectancy differed by 7 years between neighborhoods, and healthy life expectancy by 14 years (Jonker et al., 2014). Segregation is not as present in Dutch cities as compared to some other countries, and higher income families do reside in deprived neighborhoods. Therefore, the introduction of dedicated PA spaces was not restricted to lower income families only. Nearly half of the children in the intervention group were from families with net household income above Dutch average. The overrepresentation of children from higher socioeconomic groups in the Generation R Study may have contributed to this finding.

The introduction of PA spaces in deprived neighborhoods may result in, or come together with, more general neighborhood changes that could affect outdoor play. We are not aware of any structural interventions or neighborhood improvements implemented in neighborhoods where new play facilities were built, but this could have biased our results. For example, road connectivity and neighborhood safety could have been targeted by other programs in neighborhoods where new PA spaces were introduced. This may have an effect on outdoor play directly, or indirectly by mediating factors such as increasing children's independent mobility (Veitch et al., 2006, 2008; Moran et al., 2017). Further insights in mechanisms following built environment changes are needed to better understand subsequent behavioral changes (Rutter et al., 2017). Strategies to increase independent mobility should be encouraged, since this may largely influence the usage of neighborhood facilities.

To reduce health inequities in society, it is of great importance to identify strategies that improve health behaviors for those that are most at risk for developing disease later in life. In our main analyses, we did not find evidence that the introduction of PA spaces changed physical activity behaviors. Stratified analyses suggested that children from more socially disadvantaged families appear most responsive to the introduction of PA spaces, and there is possibly an increase in outdoor play and sedentary behaviors for these groups relative to more advantaged families. Municipalities should carefully verify if neighborhoods applying for a PA space are likely to benefit from the introduction of these facilities. Negative aspects may also result from the introduction of PA spaces. Earlier research showed that dedicated PA spaces had a small but negative impact on social cohesion, violence, and perceived safety (Wittebrood et al., 2011). The authors suggested that the PA spaces may attract various people, of which some may cause nuisance. This should be carefully monitored when implementing dedicated PA spaces.

It was encouraging to see a possible increase in outdoor play among these families, since these children more often do not participate in sports activities (Wijtzes et al., 2014). Interventions often lack evidence concerning the equity effects of promoting physical activity in children (Love et al., 2017). The presentation of subgroup estimates is not always appreciated, especially because they are prone to statistical malpractice (Petticrew et al., 2012). In our study, the intervention specifically target children living in more deprived neighborhoods, which justifies the decision to present subgroup estimates for population characteristics that are associated with neighborhood deprivation.

Researchers and policymakers often struggle how to evaluate the effectiveness of interventions within the built environment. There is a need to conduct more consequential research that informs policymakers how to improve population health (Galea, 2013; Nandi and Harper, 2015). Focusing on children in which the access to facilities changed during follow-up, as opposed to cross-sectional studies and studies in which children change neighborhoods, is essential for this purpose. This study showed that natural experiments can be used for policy evaluation, however, finding a setting in which a substantial part of the population is experiencing differences in exposure is challenging. New technologies, such as GPS and wearable devices to objectively measure physical activity with smaller variance, and data linkage may further improve studies on the effect on environmental changes in physical activity and underlying mechanisms. We would encourage policymakers and researchers to look for relevant natural experiments within the built environment that may have contributed to population health. As such, investing in high quality measures and a good documentation of built environment changes would help in creating evidence-based cities in which health behaviors are promoted.

5. Conclusion

The introduction of dedicated PA spaces may increase the time spent playing outdoors for children from more socioeconomically disadvantaged families. Also increases in sedentary behaviors were observed, suggesting that compensation may have taken place. Larger studies unravelling the complexity of child behavior are needed to design environments that support physical activity behaviors.

Ethics approval and consent to participate

The study was approved by the Medical Ethics Committee of the Erasmus Medical Center, Rotterdam, the Netherlands (MEC 198.782/2001/31). Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Availability of data and materials

The dataset generated for the present study is not publicly available, as participants' consent was not obtained for data sharing.

Conflicts of interest

The authors declare that they have no competing interests.

Funding

Authors' contributions

Ms. Famke Mölenberg conceptualized and designed the study, carried out the analyses, drafted the initial manuscript, and reviewed and revised the manuscript. Mr. J. Mark Noordzij contributed to the analyses, and reviewed the manuscript. Prof. Frank J. van Lenthe and Prof. Alex Burdorf conceptualized and designed the study, and reviewed the manuscript. All authors read and approved the final manuscript.

Acknowledgements

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2019.102151.

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