

Physical Activity Spaces Not Effective against Socioeconomic Inequalities in Myopia Incidence: The Generation R Study

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SIGNIFICANCE: Our findings show that non-Dutch background, lower maternal education, and lower net household income level may be new risk factors for myopia development in the Netherlands. Newly introduced physical activity spaces may not be effective enough in increasing outdoor exposure in children to reduce eye growth.

PURPOSE: The aims of this study were to evaluate socioeconomic inequalities in myopia incidence, eye growth, outdoor exposure, and computer use and to investigate if newly introduced physical activity spaces can reduce eye growth in school-aged children.

METHODS: Participants (N = 2643) from the Dutch population-based birth cohort Generation R were examined at ages 6 and 9 years. Socioeconomic inequalities in myopia incidence, eye growth, and lifestyle were determined using regression analyses. Information on physical activity spaces located in Rotterdam was obtained. Differences in eye growth between those who became exposed to new physical activity spaces (n = 230) and those nonexposed (n = 1866) were evaluated with individual-level fixed-effects models.

RESULTS: Myopia prevalence was 2.2% at age 6 years and 12.2% at age 9 years. Outdoor exposure was 11.4 h/wk at age 6 years and 7.4 h/wk at age 9 years. Computer use was 2.1 h/wk at age 6 years and 5.2 h/wk at age 9 years. Myopia incidence was higher in children with non-Dutch background, and families with lower household income and lower maternal education (odds ratio [OR], 1.081 [95% confidence interval, 1.052 to 1.112]; OR, 1.035 [95% confidence interval, 1.008 to 1.063]; OR, 1.028 [95% confidence interval, 1.001 to 1.055], respectively). Children living <600 m of a physical activity space did not have increased outdoor exposure, except those from families with lower maternal education ($\beta = 1.33$ h/wk; 95% confidence interval, 0.15 to 2.51 h/wk). Newly introduced physical activity spaces were not associated with reduction of eye growth.

CONCLUSIONS: Children from socioeconomically disadvantaged families became more often myopic than those from socioeconomically advantaged families. We did not find evidence that physical activity spaces protect against myopia for the population at large, but subgroups may benefit.



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Optom Vis Sci 2021;98:1371–1378. doi:10.1097/OPX.0000000000001809

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Myopia (nearsightedness) is a common refractive error in urban areas. The prevalence in Europe has risen dramatically from 25% of the young adults 30 years ago to 50% of the young adults today.¹ In China, up to 80% of the university students in China is myopic.² Higher degrees of myopia are associated with an increased prevalence of complications, such as myopic macular degeneration, retinal detachment, and/or glaucoma. These complications may cause irreversible visual impairment or blindness, particularly in persons with high myopia.³

The dramatic increase in myopia prevalence is likely triggered by the changing lifestyle in childhood with increasing near work and lack of outdoor exposure.^{4–6} Outdoor exposure has received

considerable attention in myopia research.⁶ Randomized controlled trials have been conducted in several Asian countries to evaluate whether myopia can be prevented by increasing outdoor time at school. The results consistently showed that children in the intervention group had less myopia compared with their peers.^{6,7} Some non-school program interventions suggested that a supportive neighborhood can promote outdoor play by providing opportunities to play outdoors.^{8–10} We recently observed socioeconomic inequalities in 6-year-olds from the Generation R Study: children from families with low income and low education had an increased prevalence of myopia, mostly because of a higher frequency of lifestyle factors.¹¹

Children from disadvantaged families often receive fewer opportunities to be outside and seem to perform more continuous near work.^{11–14} Creating an environment that is supportive for outdoor play behavior may be an effective policy for myopia prevention.

Two foundations established by Dutch sports legends (Richard Krajicek, former professional tennis player, Wimbledon champion; Johan Cruyff, former professional soccer player and coach) introduced new physical activity spaces in Dutch cities to encourage outdoor play, with a special focus on children living in deprived neighborhoods. The new physical activity spaces target children aged 6 to 18 years and contain one or more of the following: soccer field, basketball court, tennis field, or playground equipment. Some physical activity spaces additionally contain a miniathletics track, a panna court, a tennis table, a skating rink, fitness items, a volleyball field, or a dance floor. The first Krajicek Playground in Rotterdam, the Netherlands, was opened in 2001; the first Cruyff Court was opened in 2005.^{15,16}

Earlier research suggested that the introduction of these physical activity spaces in Rotterdam may increase outdoor play for children from socioeconomically disadvantaged families.¹⁵ The extent to which changes in the physical environment of the neighborhood can promote outdoor play and subsequently reduce the risk of incident myopia or eye growth is currently unknown. The purpose of this study is to evaluate (1) potential socioeconomic inequalities in myopia incidence, eye growth, outdoor exposure, and computer use in school-aged children and (2) whether newly introduced physical activity spaces can reduce eye growth, especially in children from socioeconomically disadvantaged families.

METHODS

Study Population: Generation R

Generation R is a population-based prospective cohort of 9778 pregnant women and their children who were born between April 2002 and January 2006 in Rotterdam, the Netherlands. The exact methodology of the Generation R study has been described elsewhere.¹⁷ We used data from children who were invited to the research center when they were 6 and 9 years old. Of the initial cohort, 5431 children (55.5%) participated at both visits. Children who no longer lived in Rotterdam and children with a missing or invalid residential address at age 6 or 9 years were excluded ($n = 2447$). Children with missing data on axial length at age 6 or 9 years were also excluded ($n = 341$). The final sample consisted of 2643 children: 547 already had access (<600 m) to a physical activity space at age 6 years, 230 gained access (<600 m) to a new physical activity space at age 9 years, and 1866 did not have access (>600 m) to a physical activity space during this study period. This research was reviewed by an independent ethical review board and conforms to the principles and applicable guidelines for the protection of human subjects in biomedical research. The study protocol was approved by the Medical Ethical Committee of the Erasmus Medical Centre, Rotterdam (MEC 217.595/2002/20). Written informed consent was obtained from all participants.

Eye Measurements

Ocular biometry was measured by Zeiss IOLMaster 500 at ages 6 and 9 years (Carl Zeiss MEDITEC IOLMaster, Jena, Germany). For axial length, five measurements per eye were averaged to mean axial length (in millimeters). Three measurements of corneal curvature were taken of both eyes, and mean corneal radius was calculated.

Mean axial length/corneal radius ratio was calculated by dividing axial length (in millimeters) by corneal radius (in millimeters) for both eyes and then averaged. Eye growth was defined as mean axial length/corneal radius ratio change (per year) and axial elongation (in millimeters per year), by subtracting the axial length/corneal radius ratio or axial length at age 6 years from the axial length/corneal radius ratio or axial length at age 9 years per eye, divided by the time between the measurements in years, and was then averaged. Visual acuity was measured with LEA charts at a 3-m distance by means of the Early Treatment Diabetic Retinopathy Study method at ages 6 and 9 years.¹⁸ In children with visual acuity of worse than 0.1 logarithm of the minimum angle of resolution (logMAR; Snellen visual acuity, <0.8) in at least one eye or in children with an ophthalmologic history, automated cycloplegic refractive error was performed using a Topcon KR8900 instrument (Topcon, Tokyo, Japan). Those with visual acuity of 0.1 logMAR or better who had no glasses and no ophthalmic history were classified as nonmyopic.¹⁹ Two drops (three in case of dark irises) of cyclopentolate (1%) with 5-minute interval were dispensed, and refractive error measurements were performed at least 30 minutes thereafter when pupil diameter was ≥ 6 mm. Automated cycloplegic refractive error measurement regardless of visual acuity was introduced for all children during the research phase at age 9 years. Spherical equivalent was calculated as the sum of the full spherical value and half of the cylindrical value. Myopia was defined as spherical equivalent ≤ -0.50 D in at least one eye.

Outdoor Exposure and Computer Use

Outdoor play was measured using a questionnaire filled in by the parents. At 6 years, the questions “how many days per week does your child play outside” and “approximately how long does your child play outside per day” were asked for weekend and weekdays separately. Mean weekly outdoor play was calculated by multiplying the number of days by time in minutes. Walking or cycling to and from school and computer use was processed similarly. Total outdoor exposure was calculated as the sum of playing outside and walking or cycling to and from school. At 9 years, similar questions were asked regarding outdoor play, walking, or cycling to and from school and computer use, although the question options did not specify weekend and weekdays separately.

Socioeconomic Determinants

Maternal education level when the child was 6 years old was categorized into higher (bachelor's degree, higher vocational training, university degree) and lower (less than bachelor's degree) education level based on self-report. Net household income (low, $\leq \text{€}3200/\text{month}$; high, $> \text{€}3200/\text{month}$) was collected at both time points. If net household income was missing at age 6 years, the income measured at age 9 years was imputed 9 ($n = 126$) and vice versa ($n = 120$). In accordance with Statistics Netherlands, a child's family background was classified as Dutch with or without migration based on the country of birth of the child's parents, further referred to as Dutch and non-Dutch background.

The Intervention: Exposure to Dedicated Physical Activity Spaces

The foundations provided information on the location of the physical activity spaces and the date of opening. They considered neighborhoods eligible for a physical activity space when they were deprived of accessibility to sports/play facilities, had low physical activity levels or sport participation rates among youth, or could

otherwise show that the introduction of physical activity spaces was likely to benefit children's development. The physical activity spaces were freely accessible and often supervised during peak hours. More information on the physical activity spaces can be found on the Web sites of the foundations: www.krajicek.nl and www.cruyff-foundation.org. The distance of the nearest physical activity space for each Generation R child was determined using the software QGIS.²⁰ A buffer size of 600 m was chosen based on the mean radius of a Rotterdam neighborhood in 2008.²¹ Euclidian buffers of 600 m around children's homes were calculated, and the presence of existing and new dedicated physical activity spaces within buffers was determined at the ages of 6 and 9 years.

Statistical Analyses

Baseline characteristics were presented using mean and standard deviation for continuous variables and percentages for categorical variables. The proportion of higher versus lower maternal education and household income was assessed for children with Dutch and non-Dutch background using χ^2 tests. Myopia incidence ($n = 240$ of 2467) was considered a dichotomous outcome variable; axial length/corneal radius ratio change ($n = 2643$) and axial elongation ($n = 2643$) were processed as continuous outcomes.

Socioeconomic Inequalities in Myopia Incidence, Eye Growth, Outdoor Exposure, and Computer Use

First, we assessed socioeconomic inequalities and ethnic differences in outdoor exposure and computer use at ages 6 and 9 years using linear regression analyses adjusted for age, sex, and season of data collection. Second, we tested socioeconomic inequalities and ethnic differences in myopia incidence, axial length/corneal radius ratio change, and axial elongation by logistic and linear regression analyses adjusting for age and sex. Finally, we additionally adjusted for outdoor exposure, computer use, and season of data collection at age 6 years to determine whether the identified associations could, in part, be explained by these factors.

Exposure to Physical Activity Spaces and Outdoor Exposure

We included only those children without access to a physical activity space within their neighborhood (<600 m from their home) at age 6 years ($n = 2096$). First, we assessed the association between exposure to newly introduced physical activity spaces between 6 and 9 years as the determinant and outdoor exposure at 9 years and change in outdoor exposure from 6 to 9 years as outcomes using linear regression analyses adjusted for age, sex, and season of data collection. Second, we conducted the analyses separately for children with a Dutch and non-Dutch background, from families with lower and higher net household income at baseline and lower and higher educated mothers.

Exposure to Physical Activity Spaces and Eye Growth

Fixed-effects models were used to estimate the within-person changes in exposure to physical activity spaces and within-person changes in the continuous outcomes axial length/corneal radius ratio and axial length. They allowed to control for unmeasured time-invariant and measured time-variant confounders; we therefore adjusted for the time-varying covariates age and season of data collection, and additionally for net household income and computer use.²² Fixed-effects models for binary outcome variables will drop observations for whom myopia status did not change over time, yielding considerable power issues, and myopia incidence was

therefore not investigated. Again, these analyses were conducted separately for children from families with lower and higher net household income at baseline, lower and higher educated mothers, and a Dutch and non-Dutch background. The following sensitivity analyses were performed: First, we excluded children who were already myopic at age 6 years from the analyses because their eyes may grow faster than those who were not yet myopic. Second, we repeated the analyses using buffers of 400 and 800 m to explore whether the effects reported were sensitive to the size of buffers. Third, we excluded children for whom the data were collected within 6 months after the introduction of the new physical activity space, to account for the novelty effect and ensure that long-term impact is obtained. Fourth, we excluded children who moved houses within the study period. All analyses were conducted in R statistical software version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria), using the *plm* package for the fixed-effects analyses.^{23,24}

RESULTS

The study cohort consisted of 2643 children, with mean ages of 6.1 years at baseline and 9.8 years at follow-up; 50.5% were female, and 63% had a Dutch background. Parents from children with non-Dutch background were mostly from Africa (8.8%), Europe (8.5%), Suriname (6.5%), Turkey (5.8%), and Asia (3.3%). Almost half of the children had a mother with a low education level (41.1%) and a low net household income (48.4%). Myopia prevalence was 2.2% at age 6 years, which increased to 12.2% at age 9 years. Outdoor exposure was 11.4 h/wk at age 6 years, which decreased to 7.4 h/wk at age 9 years, whereas computer use was 2.1 and 5.2 h/wk, respectively (Table 1). Families with a Dutch background more often had a higher educated mother (67.8% vs. 43.8%, $P < .001$) and a higher household income (65.2% vs. 28.7%, $P < .001$) than families with a non-Dutch background.

Children with non-Dutch background had -1.46 (95% confidence interval, -2.10 to -0.82) and -0.55 (95% confidence interval, -0.96 to -0.14) h/wk outdoor exposure at ages 6 and 9 years, and 0.97 (95% confidence interval, 0.72 to 1.22) and 1.33 (95% confidence interval, 0.87 to 1.80) h/wk more computer use at ages 6 and 9 years than those with Dutch background. Children from families with lower net household income had 1.11 (95% confidence interval, 0.86 to 1.35) and 1.02 (95% confidence interval, 0.57 to 1.47) h/wk more computer use at ages 6 and 9 years than those from families with higher net household income. Children from families with lower maternal education level had 0.63 (95% confidence interval, 0.23 to 1.03) h/wk more outdoor exposure at age 9 years, and 1.02 (95% confidence interval, 0.78 to 1.26) and 0.85 (95% confidence interval, 0.40 to 1.29) h/wk more computer use at, respectively, ages 6 and 9 years than those from families with higher maternal education level. No significant differences in outdoor exposure were identified for maternal education level at 6 years and net household income levels at 6 and 9 years (see Appendix Figure A1, available at <http://links.lww.com/OPX/A547>, Appendix Figure A2, available at <http://links.lww.com/OPX/A548>, and Appendix Table A1, available at <http://links.lww.com/OPX/A546>).

Myopia incidence between ages 6 and 9 years was higher in children with non-Dutch background, and families with lower net household income and lower maternal education (OR, 2.39 [95% confidence interval, 1.74 to 3.30]; OR, 1.52 [95% confidence interval, 1.10 to 2.09]; OR, 1.38 [95% confidence interval, 1.00 to 1.90]; respectively; Fig. 1). Axial length/corneal radius ratio

TABLE 1. General characteristics

Generation R cohort (n = 2643)	Age 6 y	Missing (%)	Age 9 y	Missing (%)
Age, mean \pm SD (y)	6.1 \pm 0.4	0.0	9.8 \pm 0.3	0.0
Sex (% ♀)	50.1	0.0		
Ethnic background (% Dutch)	62.8	0.1		
Myopia (%)	2.2	1.0	12.2	3.6
Axial length/corneal radius ratio, mean \pm SD	2.87 \pm 0.07	0.0	2.97 \pm 0.09	0.0
Axial length, mean \pm SD (mm)	22.34 \pm 0.73	0.0	23.10 \pm 0.83	0.0
Maternal education (% low)	41.1	1.0		
Net household income (% low)	48.4	1.2	45.1	1.2
Outdoor exposure, mean \pm SD (h/wk)	11.38 \pm 7.61	19.9	7.39 \pm 5.12	5.1
Computer use, mean \pm SD (h/wk)	2.08 \pm 3.08	8.7	5.20 \pm 5.63	8.6

SD = standard deviation.

change and axial elongation were greater in children with non-Dutch background ($\beta = 0.003$ [95% confidence interval, 0.001 to 0.004] and $\beta = 0.019$ [95% confidence interval, 0.012 to 0.027], respectively), and axial length/corneal radius ratio change was greater in children from families with lower household income ($\beta = 0.001$; 95% confidence interval, $6.0E^{-5}$ to 0.002). No significant differences were identified for maternal education level. Adjusting for outdoor exposure, computer use, and season of data collection at 6 years slightly decreased the associations (Appendix Table A2, available at <http://links.lww.com/OPX/A546>).

Children who gained access to a physical activity space had 7.43 h/wk outdoor exposure at age 9 years, whereas children who did not gain access had 7.25 h/wk outdoor exposure. However, living within 600 m of a newly introduced physical activity space was not significantly associated with outdoor exposure at age 9 years ($\beta = 0.43$ h/wk; 95% confidence interval, -0.26 to 1.12 h/wk) or change in outdoor exposure from ages 6 to 9 years ($\beta = 0.08$ h/wk; 95% confidence interval, -1.12 to 1.28 h/wk; Table 2). Stratified analyses showed that children from families with lower maternal education had 8.26 h/wk outdoor exposure at age 9 years if they lived

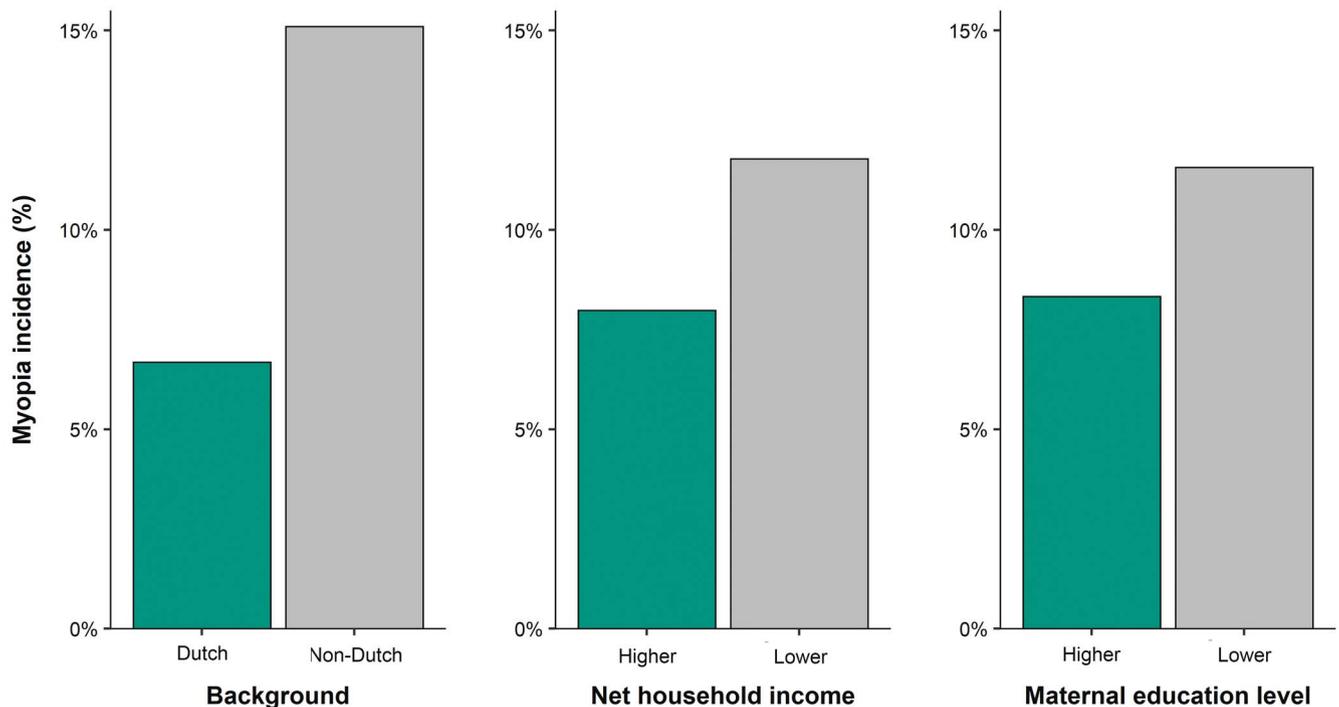


FIGURE 1. Bar chart depicting the proportion of children with incident myopia from ages 6 to 9 years, stratified by ethnic background (left), net household income at baseline (middle), and maternal education level (right).

TABLE 2. Longitudinal analyses of the introduction of physical activity spaces on outdoor exposure at age 9 years and the change in outdoor exposure from 6 to 9 years, stratified by ethnic background, net household income at baseline, and maternal education level

	Intervention/control (n)	Outdoor exposure at age 9 y		Intervention/control (n)	Change in outdoor exposure	
		β (95% CI) (h/wk)	P		β (95% CI) (h/wk change)	P
All*	218/1779	0.429 (−0.262 to 1.120)	.22	171/1455	0.080 (−1.118 to 1.278)	.90
Ethnic background†						
Dutch	115/1234	0.274 (−0.648 to 1.197)	.56	98/1057	0.149 (−1.369 to 1.667)	.85
Non-Dutch	103/545	0.611 (−0.443 to 1.665)	.26	73/398	0.156 (−1.832 to 2.144)	.88
Net household income*						
Higher	104/1007	0.225 (−0.704 to 1.153)	.64	85/855	−0.609 (−2.184 to 0.966)	.45
Lower	113/754	0.783 (−0.259 to 1.824)	.14	85/587	0.640 (−1.224 to 2.505)	.50
Maternal education*						
Higher	123/1107	−0.262 (−1.117 to 0.594)	.55	103/929	−0.928 (−2.358 to 0.501)	.20
Lower	92/658	1.329 (0.150 to 2.508)	.03	66/517	1.676 (−0.488 to 3.840)	.13

*Adjusted for season of data collection, age, sex, and ethnic background. †Adjusted for season of data collection, age, and sex. CI = confidence interval.

within 600 m of a newly introduced physical activity space and 7.33 h/wk if they lived farther away than 600 m, resulting in 1.33 h/wk (95% confidence interval, 0.15 to 2.51 h/wk) more outdoor exposure associated with gaining access to a physical activity space when adjusting for season of data collection, age, sex, and ethnic background (Table 2).

Children who gained access to a physical activity space had 0.22-mm axial elongation per year, whereas children who did not gain access had 0.21-mm axial elongation per year. The fixed-effects model showed that the introduction of physical activity spaces within 600 m from home between the age of 6 and 9 years had no effect on

axial length/corneal radius ratio change ($\beta = 0.00$; 95% confidence interval, −0.00 to 0.01) or axial elongation ($\beta = 0.03$ mm/y; 95% confidence interval, −0.01 to 0.07 mm/y). Adding the covariates household income and computer use to the model did not change the results, as well as stratified analyses by net household income, maternal education level, and ethnic background (Table 3). Sensitivity analyses excluding myopic children at baseline, with buffer sizes of 400 and 800 m; excluding children who lived less than 6 months within 600 m of a new physical activity space; and excluding children who moved houses yielded similar results as the main analyses (Appendix Table A3, available at <http://links.lww.com/OPX/A546>).

TABLE 3. Effect of the introduction of physical activity spaces on axial length/corneal radius ratio change and axial elongation using fixed-effects analyses, stratified by ethnic background, net household income, and maternal education

	Intervention/control (n)	Axial length/corneal radius ratio change		Axial elongation		
		β (95% CI) (1 unit change/y)	P	β (95% CI) (mm/y change)	P	
Physical activity space*	230/1866	0.004 (−0.002 to 0.010)	.16	0.030 (−0.012 to 0.073)	.16	
Physical activity space†	196/1580	0.002 (−0.004 to 0.008)	.50	0.012 (−0.033 to 0.058)	.60	
Lower net household income		−1.2E ^{−4} (−0.005 to 0.005)	.96	−0.007 (−0.043 to 0.030)	.73	
Computer use		3.4E ^{−4} (−5.3E ^{−5} to 7.4E ^{−4})	.09	0.003 (1.2E ^{−4} to 0.006)	.04	
Subgroup analyses						
Ethnic background†						
Dutch	112/1135	−0.001 (−0.008 to 0.007)	.81	−0.003 (−0.057 to 0.051)	.92	
Non-Dutch	84/443	0.003 (−0.009 to 0.015)	.60	0.009 (−0.075 to 0.093)	.83	
Net household income‡						
Higher	98/916	−0.003 (−0.012 to 0.005)	.47	−0.015 (−0.077 to 0.047)	.63	
Lower	98/664	0.007 (−0.002 to 0.016)	.13	0.037 (−0.029 to 0.104)	.28	
Maternal education†						
Higher	113/995	0.006 (−0.002 to 0.014)	.12	0.038 (−0.020 to 0.097)	.20	
Lower	81/576	−0.004 (−0.014 to 0.006)	.44	−0.022 (−0.094 to 0.050)	.55	

*Adjusted for age and season of data collection. †Adjusted for age, season of data collection, net household income, and computer use. ‡Adjusted for age, season of data collection, and computer use. CI = confidence interval.

DISCUSSION

This study identified distributions of myopia, eye growth, outdoor exposure, and computer use across socioeconomic groups, and investigated whether population health can be improved by physical activity spaces. We followed up children who did not have a physical activity space in their neighborhood at age 6 years but gained access before the age of 9 years, and estimated the effect on eye growth. We found that myopia incidence was higher in children from socioeconomically disadvantaged families and in children with non-Dutch background. This difference could, in part, be explained by lifestyle factors. Computer use was higher in these children, whereas outdoor exposure was significantly lower in children with non-Dutch background. Children from families with lower educated mothers who became exposed to new physical activity spaces in their neighborhood had 1.33 h/wk more outdoor exposure than those without access to physical activity spaces. This increase was not enough to significantly diminish eye growth.

Strength and Limitations

Strengths of the study were the population-based prospective cohort design, the large sample size, the comprehensive set of socioeconomic determinants, and the innovative use of an experimental approach to analyze observational data.²⁵ This approach enabled removal of the effects of time-invariant causes, even those unmeasured, such as people's choice to live in a neighborhood with many opportunities for children to play outdoors.²² Because fixed-effects models do not account for time-variant factors, we controlled for age, change in net household income, and change in computer use. To ensure that we addressed long-term physical activity exposure, we performed sensitivity analyses excluding children who were only exposed <6 months. The limitations included a relatively large amount of missing data on outdoor exposure, the use of questionnaires to determine outdoor exposure and computer use, and the lack of information on the playtime spent at physical activity spaces.

Traditionally, high education and urbanization were the strongest risk factors for myopia all over the world.^{1,26} Excessive amounts of near work and lack of outdoor exposure may explain this association.^{26,27} In Asia, children particularly from higher educated families attending private or cram schools were more often myopic.^{28,29} In Europe, this trend might be changing. In the European Eye Epidemiology consortium, the association with education was strong in the older age groups but became less apparent in younger age groups,¹ recent studies from Ireland and Germany did not find any association between socioeconomic status and myopia in children,^{14,30} and previous results from Generation R data at age 6 years showed that low family income and low maternal education predisposed to myopia prevalence.¹¹ This suggests a shift in myopia risk from children from highly educated families to children from socioeconomically disadvantaged families in Europe. Our current data from children at age 9 years reinforce this notion, as newly developed myopia occurred more often in children from low household income and low maternal education, and children from non-Dutch families had a larger change in the axial length/corneal radius ratio and axial elongation. Health problems may shift from higher to lower socioeconomic groups, in a different tempo between countries. This is a known phenomenon, illustrated well by, for example, a social transition in smoking and higher body mass index from the more affluent to socioeconomically disadvantaged

members of society.³¹ Several reasons may explain the reversed association between socioeconomic factors and myopia in our study as compared with previous studies. First, only children living in the city of Rotterdam were included in the analyses, thereby not influenced by living environment (urban vs. rural areas). Because higher educated people more often live in urban areas, previous studies on socioeconomic position and myopia may have been partly confounded by urbanization.^{28,29} Second, the effect of education is not visible yet in 6- and 9-year-old children because they go to generally similar primary schools, in contrast to studies focusing on education and myopia in adults or adolescents.^{26,32} Conflicting results have been reported about household income and myopia in recently published studies.^{33,34} Third, children from higher socioeconomic position and native Dutch children more often participate in sports than children from lower socioeconomic position and ethnic minorities in Generation R, which may result in less myopia in these groups.¹² Fourth, academic pressure from parents may be stronger in East Asian countries than in European countries as illustrated by the high prevalence of cram school attendance in East Asia.³⁵

Non-Dutch background was the most pronounced association with myopia at an early age in our study and was also observed for axial elongation and change in the axial length/corneal radius ratio. From the 1960s onward, the immigration number increased because of the recruitment of low-skilled guest workers and refugees, and later because of family reunification.³⁶ In our study, parents from families with non-Dutch background were mostly from Europe or Africa; only a small proportion (3.3%) was from Asia. After adjustment for outdoor exposure, computer use, and season of data collection, the association between ethnic background and myopia became slightly less strong. Studies on myopia in African adults reported low prevalence³⁷; we therefore believe that our findings are not explained by a different genetic background. Residual confounding of environmental factors may be more likely, especially because mothers from families with non-Dutch background were more often lower educated and families with non-Dutch background more often had a lower household income.

Environmental factors are considered the most likely cause of the worldwide increased myopia incidence.³⁸ Lack of outdoor exposure is an established risk factor and has been a target for successful intervention studies.^{6,7} There is also growing evidence for increased use of computers and handheld screens.^{39,40} In this study, we found that children from families with low household income, low maternal education, and non-Dutch background had ~1 h/wk more computer use, and children with non-Dutch background had 0.5 to 1.5 h/wk less outdoor exposure than their peers. This may explain, in part, the socioeconomic and ethnic background inequalities in myopia incidence in our cohort.¹¹ Other studies also reported that increased sedentary behavior as well as computer and handheld device use, and lack of outdoor exposure are more common among socioeconomically disadvantaged families.^{11,12,41} Parents from these families may have less stricter rules concerning noneducational screen time, which could explain the difference.⁴²

Two hours per day of outdoor exposure is currently recommended to prevent children from myopia or myopia progression.⁴³ Most of the children in our cohort did not meet this advice, especially when they reached the age of 9 years and those with non-Dutch background. Previous research showed that children from socioeconomically disadvantaged families or ethnic minorities less often participate in sports and outdoor play.^{12,44} We therefore performed our analyses in the whole group and in several subgroups. The introduction of new physical activity spaces within the

neighborhood was associated with 0.19 h/d extra outdoor exposure among children from families with lower maternal education; outdoor exposure was 1.04 h/d in those without physical activity space and 1.19 h/d in those who gained access to a new physical activity space. No differences in outdoor exposure were identified in the other subgroups. Hence, no differences in eye growth were identified. School-based randomized controlled trials showed that at least 0.67 h/d extra outdoor exposure was needed to prevent children from myopia.^{6,7} Increased surrounding greenness was associated with 0.13 h/wk increased time spent playing in green spaces and a reduced risk of incident spectacle use in the BREATHE study.⁴⁵ A recent review concluded that the presence of a safe and green neighborhood was positively associated with outdoor play.⁴⁶ Increased surrounding greenness may be more effective against myopia prevention than the physical activity spaces in our study because the physical activity spaces were mainly placed in deprived and perhaps less safe neighborhoods. Previous research showed that playground use was higher at Krajicek physical activity spaces as compared with regular playgrounds in deprived areas.¹⁶

Benefits of Krajicek and Cruyff spaces are the supervision from community organizations and organized events. The introduction of these physical activity spaces may have led to a shift from another outdoor play location rather than an increase in outdoor play. Unfortunately, we did not have information about the children's outdoor play locations to investigate this. More research on neighborhood interventions that are effective in increasing outdoor exposure is needed, as indoor activities such as screen time behavior in children is becoming extremely popular.⁴⁷

In conclusion, the results of our study showed that myopia incidence is more common among primary school-aged children from socioeconomically disadvantaged families, which may be partly explained by differences in outdoor exposure and computer use. Physical activity spaces do not seem to increase outdoor exposure to such extent that it reduces eye growth in all children, although subgroups may benefit. More far-stretching strategies are needed to increase outdoor play, reduce noneducational screen time in school-aged children in the entire population, and consequently reduce the risk of myopia and myopia progression.

ARTICLE INFORMATION

Supplemental Digital Content: Appendix Table A1, available at <http://links.lww.com/OPX/A546>. Cross-sectional analyses of ethnic background, net household income, and maternal education level on outdoor exposure and computer use at ages 6 and 9 years.

Appendix Table A2, available at <http://links.lww.com/OPX/A546>. Longitudinal analyses of ethnic background, net household income, and maternal education level on myopia incidence, axial length/corneal radius ratio change, and axial elongation.

Appendix Table A3, available at <http://links.lww.com/OPX/A546>. The effect of the introduction of physical activity spaces on axial length/corneal radius ratio change and axial elongation using fixed effects, excluding baseline myopia, using buffer zones of 400 and 800 m; excluding children who lived less than 6 months near a physical activity space; and excluding children who moved houses within the study period.

Appendix Figure A1, available at <http://links.lww.com/OPX/A547>. Boxplots depicting outdoor exposure at ages 6 and 9 years in hours per week, stratified by ethnic background, net household income at baseline, and maternal education level. The box represents the interquartile range (the 25th and 75th percentiles), and the horizontal line is drawn at the median. The whiskers indicate $-1.5 * 25\text{th percentile}$ and $-1.5 * 75\text{th percentile}$.

Appendix Figure A2, available at <http://links.lww.com/OPX/A548>. Boxplots depicting computer use at ages 6 and 9 years in hours per week, stratified by ethnic background, net household income at baseline, and maternal education level. The box represents the interquartile range (the 25th and 75th percentiles), and the horizontal line is drawn at the median. The whiskers indicate $-1.5 * 25\text{th percentile}$ and $-1.5 * 75\text{th percentile}$.

Submitted: December 2, 2020

Accepted: July 5, 2021

Funding/Support: ODAS Stichting (2017-04; to CCWK); Oogfonds (2016-23; to CCWK); Uitzicht (Oogfonds, Maculafonds, LSBS; 2017-28; to CCWK); Nederlandse Organisatie voor Wetenschappelijk Onderzoek (91815655;

to CCWK); and H2020 European Research Council (648268; to CCWK).

Conflict of Interest Disclosure: None of the authors have reported a financial conflict of interest.

Study Registration Information: The study protocol was approved by the Medical Ethical Committee of the Erasmus Medical Centre, Rotterdam (MEC 217.595/2002/20).

Author Contributions and Acknowledgments: Conceptualization: CCWK; Data Curation: CAE, CCWK; Formal Analysis: CAE, FJMM; Funding Acquisition: CCWK; Investigation: CAE, JWLT, JRP, HR; Methodology: CAE, FJMM, JAL, FJvL, CCWK; Supervision: CCWK; Visualization: CAE; Writing – Original Draft: CAE; Writing – Review & Editing: FJMM, JWLT, JRP, JAL, HR, FJvL, CCWK.

The Generation R Study is conducted by the Erasmus Medical Center in close collaboration with the School of Law and Faculty of Social Sciences of the Erasmus University Rotterdam; the Municipal Health Service Rotterdam area, Rotterdam; the Rotterdam Homecare Foundation, Rotterdam; and the Stichting Trombosedienst & Artsenlaboratorium Rijnmond (STAR-MDC), Rotterdam. The authors gratefully acknowledge the contribution of children and parents, general practitioners, hospitals, midwives, and pharmacies in Rotterdam. They also would like to thank Mark Noordzij for the calculation of the distance of the nearest physical activity space from each child's home address using QGIS software.

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