

Outdoor Activity during Class Recess Reduces Myopia Onset and Progression in School Children

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Purpose: The aim of this study was to investigate the effect of outdoor activity during class recess on myopia changes among elementary school students in a suburban area of Taiwan.

Design: Prospective, comparative, consecutive, interventional study.

Participants: Elementary school students 7 to 11 years of age recruited from 2 nearby schools located in a suburban area of southern Taiwan.

Intervention: The children of one school participated in the interventions, whereas those from the other school served as the control group. The interventions consisted of performing a recess outside the classroom (ROC) program that encouraged children to go outside for outdoor activities during recess. The control school did not have any special programs during recess.

Main Outcome Measures: Data were obtained by means of a parent questionnaire and ocular evaluations that included axial length and cycloplegic autorefractometry at the beginning and after 1 year.

Results: Five hundred seventy-one students were recruited for this study, of whom 333 students participated in the interventional program, and 238 students were in the control school. At the beginning of the study, there were no significant differences between these 2 schools with regard to age, gender, baseline refraction, and myopia prevalence (47.75% vs. 49.16%). After 1 year, new onset of myopia was significantly lower in the ROC group than in the control group (8.41% vs. 17.65%; $P < 0.001$). There was also significantly lower myopic shift in the ROC group compared with the control group (-0.25 diopter [D]/year vs. -0.38 D/year; $P = 0.029$). The multivariate analysis demonstrated that the variables of intervention of the ROC program and higher school year proved to be a protective factor against myopia shift in nonmyopic subjects ($P = 0.020$ and $P = 0.017$, respectively). For myopic subjects, school year was the only variable significantly associated with myopia progression ($P = 0.006$).

Conclusions: Outdoor activities during class recess in school have a significant effect on myopia onset and myopic shift. Such activities have a prominent effect on the control of myopia shift, especially in nonmyopic children.

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Myopia has become a public health issue worldwide in recent years.^{1–5} It is 1 of the 5 immediate priorities for the Vision 2020 initiative of the World Health Organization.^{6–8} Myopia is very prevalent in East Asia, especially in countries such as Taiwan,^{9–11} Singapore,^{3,4,12} and Japan.¹³ Studies have shown that myopia progresses faster when it develops in children at a younger age.^{14,15} Early onset of myopia is associated with high myopia in adult life.^{16–18} High myopia is a significant public health problem because of its association with increased risk of several ocular diseases including cataract, glaucoma, retinal detachment, myopic retinal degeneration, visual impairment, and blindness.^{19–21} Therefore, it may be important to postpone myopia onset as late as possible to keep children in a nonmyopic state for longer. In addition, retarding myopia progression to keep myopic children at low myopic status until adulthood may prevent future complications resulting from high myopia.

Recent evidence suggests that increased outdoor activities and reduced long-term near work could help to prevent myopia.^{22–28} Nevertheless, most are cross-sectional studies and there is a lack of interventional studies on the effects of outdoor activity on myopia control in the literature. This study investigates the effects of outdoor activity during class recess on myopia changes among school children.

Patients and Methods

This was a prospective, interventional study. Two elementary schools in a suburban area of Southern Taiwan near Kaohsiung Chang Gung Memorial Hospital were included in this study. The 2 public schools were selected based on the similar socioeconomic status of both the parents and communities. Both schools were in typical suburban areas and they were located in 2 adjacent districts less than 5 kilometers apart. All participants were Chinese children, and the health status of the children was similar in these 2

Table 1. Baseline Demographic Characteristics, Spherical Equivalent Refraction, and Changes in Different Groups

Characteristics	Recess Outside Classroom Group (n = 333)	Control Group (n = 238)	P Value
Boys/girls	1.03/1	1.09/1	0.750
Mean age±SD (yrs)	8.89±1.33	9.02±1.39	0.263
Mean baseline SER±SD (D)	-0.78±1.76	-0.95±1.93	0.249
Nonmyopia/myopia	1.09/1	1.03/1	0.739
Atropine treatment in myopic children (yes/no)	0.41/1	0.24/1	0.079
Mean final SER±SD (D)	-1.03±1.84	-1.33±1.92	0.061
Mean myopic shift±SD (D/year)	-0.25±0.68	-0.38±0.69	0.029*

D = diopters; SD = standard deviation; SER = spherical equivalent refraction.
*Statistically significant ($P < 0.05$).

schools. This study was approved by the Institutional Review Board at the Chang Gung Memorial Hospital and adhered to the Declaration of Helsinki. School children 7 to 11 years of age were invited to participate. The parents and children were provided with an explanation of the study, and the parents gave consent for their children’s participation. Of the 2 schools, one participated in the interventions, whereas the other school served as the control. The interventions consisted of carrying out a recess outside the classroom (ROC) program in which the classroom lights were turned off, classrooms were emptied, and all children were encouraged to go outside of the classroom for outdoor activities during recess time. The total daily recess time in school was 80 minutes (10, 20, and 10 minutes in both the morning and afternoon), and the total weekly recess time was approximately 6.7 hours. The control school did not have any special program during recess. Both schools had 2 hours for outdoor physical education per week.

In the 2 elementary schools, the children from school year 1 (7 years of age), school year 2 (8 years of age), school year 3 (9 years of age), school year 4 (10 years of age), and school year 5 (11 years of age) were included in this study. They were examined annually in 2009 and 2010. In both schools, the first and second refraction measurements were performed at the same time of year (February through March). Myopia was defined as at least -0.5 diopters (D) of spherical equivalent refraction (SER) on cycloplegic autorefraction performed using an autorefractometer (KR-7000/8100; Topcon, Tokyo, Japan). Corneal anesthesia was used to minimize the discomfort from the cycloplegic drops. For cycloplegia, 1 drop of 0.5% proparacaine was followed by 1 drop of 1% tropicamide (Mydracyl; Alcon, Puurs, Belgium) and 1% cyclopentolate hydrochloride (Cyclogyl; Alcon Laboratories, Fort Worth, TX) administered 5 minutes apart. Measurements were obtained 30 minutes after the initial drop instillation. Five to 8 consecutive readings were obtained for each child. Axial length measurement was obtained using an ultrasound biometer A-scan (AL-100, Tomy, Nagoya, Japan) by contact method. Children with best-corrected visual acuity not achieving 20/25 or diagnosed with amblyopia were excluded from this study. Because orthokeratology affects autorefraction readings, subjects with orthokeratology also were excluded from this study.

Parents provided information on parental myopia through a survey. Parents completed a survey form that asked the following question: What is the estimated frequency your child performs the following activities outside of regular school hours during each week of the school year? (Please check the appropriate box: often (more than 3 times and more than 1 hour each time), seldom, or none? The activities listed were: reading books, performing other close-range activities (e.g., playing piano or violin, writing calligraphy, painting), playing computer or video games, watching tele-

vision or playing television games, and engaging in outdoor or sports activities. Additionally, other questions about myopia included, Have you received any treatment for myopia, such as atropine or orthokeratology?

For homogenous comparison of eye refraction data, analyses were conducted on the SER of the right eye only, because refractive error was highly correlated between the right and left eyes ($r = 0.92$). In addition, the SER and axial length have moderate correlation ($r = 0.67$). The extracted data were obtained from the right eye of subjects and were used only once. The SER records obtained during the initial survey were collected for analysis from the beginning of the ROC program up to the end of the final 1-year follow-up. The progression of myopia was calculated as the change in spherical equivalent refraction (diopters) during 1 year. The relationship between the analysis variables and myopia was assessed by chi-square tests and *t* tests, respectively. Simple linear regression and multiple linear regression analyses were conducted to investigate the association of factors with myopic progression. The continuous variables included school year (in years) and baseline SER (diopters). The dichotomous variables (coded by 1 and 0) included gender (1 = boys vs. 0 = girls), myopic parent (1 = yes vs. 0 = no), reading and writing (1 = frequent vs. 0 = seldom or none), computer use (1 = frequent vs. 0 = seldom or none), other near work (1 = frequent vs. 0 = seldom or none), television watching (1 = frequent vs. 0 = seldom or none), outdoor activity after school (1 = frequent vs. 0 = seldom or none), and ROC program (1 = yes vs. 0 = no). All data analyses were performed with commercially available software SAS version 9.1.3 (SAS, Inc, Cary, NC).

Results

A total of 571 children were enrolled in this study. There were 333 children in the ROC interventional group and 238 in the control group (Table 1). The boy-to-girl ratio was 1.03:1 in the treatment group and 1.09:1 in the control group. The mean age ± standard deviation at the beginning of the study was 8.89±1.33 years in the ROC group and 9.02±1.39 years in the control group. The initial mean spherical equivalents were -0.78±1.76 D in the ROC group and -0.95±1.73 D in the control group. The myopia prevalence was 47.75% (159/333) in the ROC group and 49.16% (117/238) in the control group. The proportion of myopic children receiving atropine treatment was 28.93% (46/159) in the ROC group and 19.66% (23/117) in the control group. There were no significant differences between the 2 groups with respect to gender, age, baseline SER, baseline myopia prevalence, and atropine treatment in myopic children ($P = 0.750$, $P = 0.263$, $P = 0.249$, $P = 0.739$,

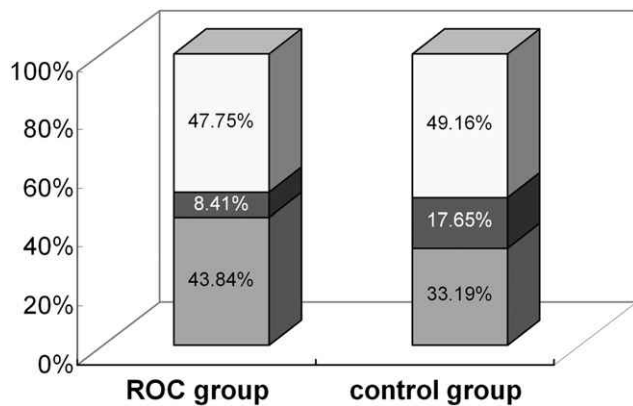


Figure 1. Bar graph showing the incidence of new myopia onset of the 2 groups in the follow-up. ROC = recess outside the classroom. □, initial myopia; ■, new onset myopia; ■, initial and final no myopia.

and $P = 0.079$, respectively). From the questionnaire, the estimated time spent outdoors after school was 2.5 ± 3.0 hours per week in the ROC group and 2.3 ± 3.2 hours per week in the control group. There was no significant difference ($P = 0.353$).

At the end of the 1-year follow-up, new cases of myopia onset during the study period were significantly lower in the ROC group than in the control group (8.41% vs. 17.65%; $P = 0.001$; Fig 1). In addition, the SERs at the final examination were -1.03 ± 1.84 D in the ROC group and -1.33 ± 1.92 D in the control group ($P = 0.061$). The mean progression of refractive error in the myopic direction was significantly lower in the ROC group than in the control group (-0.25 ± 0.68 D, compared with -0.38 ± 0.69 D; $P = 0.029$; Table 1). Among nonmyopic subjects, the mean progression of refractive error in the myopic direction was significantly lower in the ROC group than in the control group (-0.26 ± 0.61 D vs. -0.44 ± 0.64 D; $P = 0.020$). Among myopic subjects without atropine treatment, the mean myopia progression was not significantly different between the ROC group and the control group (-0.20 ± 0.69 D vs. -0.37 ± 0.67 D; $P = 0.125$). Among myopic subjects with atropine treatment, the mean myopia progression was not significantly different between the ROC group and the control group (-0.28 ± 0.57 D vs. -0.31 ± 0.44 D; $P = 0.850$). The outdoor activity did not further assist the effects of atropine in the retardation of myopic progression.

There were 295 subjects without myopia and 276 subjects with myopia initially. Among myopic subjects, 69 (25%) received an atropine eye drop treatment for the control of myopia progression during the study period. Among nonmyopic subjects, after multiple linear regression analysis, participants in the ROC program were associated with less myopic shift than the controls (0.18 D/year; 95% confidence interval, 0.03–0.33; $P = 0.020$), and each additional school year was associated similarly with less in myopic shift (0.07 D/year; 95% confidence interval, 0.01–0.12; $P = 0.017$; Table 2). Participation in the ROC program, together with higher school year, proved to be a protective factor against myopia shift. Other variables such as gender, myopic parents, baseline SER, reading and writing activity, computer use, other near-work activities, television, and outdoor activity after school were not statistically significant. For myopic subjects, school year was the only variable associated significantly with myopia progression ($P = 0.006$; Table 3). Higher school year students had more myopic progression.

Discussion

This study showed that outdoor activity during class recess was effective in preventing myopia onset and myopic shift among elementary school students in a suburban area of Taiwan. This is the first study to report on modifying educational policy through the educational system to retard myopic shift. Rose et al²⁹ have compared the high prevalence of myopia of children of Chinese ethnicity in Singapore and the low prevalence of myopia in Sydney. They found that outdoor activity is an important protective factor against myopia and they identified the link to the educational system. Because children spend a lot of time in school, intervention from the educational system is a direct and practical approach to tackle the increasing prevalence of myopia.

There are 2 interventional aspects to the ROC program regarding the behavior of school children. First, it interrupts near and midrange work during the time in the classroom. The study by Ip et al³⁰ showed that continued reading is associated with myopia. The intensity of near-range visual work is a more important factor with myopia compared with the total duration. The ROC program provides a break from continued near-range work and reduces its intensity. Second, the ROC program increases outdoor activity duration for school children. Recently, outdoor activity has become an important protective factor against myopia.^{24,26,28} Additional beneficial effects from the ROC program include contributing to a reduction in childhood obesity and saving energy while reducing carbon emissions by turning off lights during the recess.

Table 2. Multivariate Analysis of Factors Associated with Myopia Shift in Nonmyopic Schoolchildren

	Myopic Shift, Adjusted Estimate (n = 295; D/yr)	P Value
School year (yrs)	0.07 (0.01–0.12)	0.017*
Gender (boys vs. girls)	0.02 (–0.13 to 0.16)	0.794
Baseline SER (D)	–0.12 (–0.24 to 0.02)	0.086
Myopic parent (yes vs. no)	–0.01 (–0.15 to 0.14)	0.935
Reading/writing (frequent vs. seldom or none)	–0.04 (–0.20 to 0.11)	0.547
Computer (frequent vs. seldom or none)	0.10 (–0.08 to 0.27)	0.279
Other near work (frequent vs. seldom or none)	–0.03 (–0.21 to 0.15)	0.279
TV (frequent vs. seldom or none)	–0.03 (–0.32 to 0.24)	0.804
Outdoor activity after school (frequent vs. seldom or none)	0.07 (–0.07 to 0.22)	0.329
ROC program (yes vs. no)	0.18 (0.03–0.33)	0.020*

D = diopters; ROC = recess outside the classroom; SER = spherical equivalent refraction; TV = television.

Values in parentheses are 95% confidence intervals. The dichotomous variables (coded by 1 and 0) included gender (1 = boys vs. 0 = girls); myopic parent; ROC program (1 = yes vs. 0 = no); and reading/writing, computer, other near work, TV, and outdoor activity after school (1 = frequent vs. 0 = seldom or none).

*Statistically significant.

†Includes crafts and playing musical instruments.

Table 3. Multivariate Analysis of Factors Associated with Myopia Shift in Myopic Schoolchildren (n = 276)

	Myopic Shift, Adjusted Estimate (Diopters/Year)	P Value
School year (yrs)	-0.10 (-0.17 to -0.03)	0.006*
Gender (boys vs. girls)	0.07 (-0.11 to 0.26)	0.435
Baseline SER (D)	0.03 (-0.03 to 0.09)	0.320
Myopic parent (yes vs. no)	0.07 (-0.15 to 0.29)	0.515
Reading/writing (frequent vs. seldom or none)	0.16 (-0.05 to 0.37)	0.126
Computer (frequent vs. seldom or none)	-0.08 (-0.27 to 0.12)	0.453
Other near work [†] (frequent vs. seldom or none)	-0.01 (-0.25 to 0.22)	0.914
TV (frequent vs. seldom or none)	-0.19 (-0.53 to 0.15)	0.276
Outdoor activity after school (frequent vs. seldom or none)	0.09 (-0.10 to 0.28)	0.340
Atropine treatment (yes vs. no)	0.02 (-0.20 to 0.23)	0.877
ROC program (yes vs. no)	0.12 (-0.06 to 0.31)	0.183

D = diopters; ROC = recess outside the classroom; SER = spherical equivalent refraction; TV = television.

Values in parentheses are 95% confidence interval. The dichotomous variables (coded by 1 and 0) included gender (1 = boys vs. 0 = girls); myopic parent; atropine treatment; ROC program (1 = yes vs. 0 = no); and reading/writing, computer, other near work, TV, and outdoor activity after school (1 = frequent vs. 0 = seldom or none).

*Statistically significant.

[†]Includes crafts and playing musical instruments.

Onset of myopia varies from site to site. In East Asia, the onset of myopia in lower-grade primary school years is common.^{11,29} In Europe, it is common in lower secondary schooling.^{31,32} As soon as myopia occurs, myopia progresses quickly until early adulthood.³³⁻³⁵ Early onset of myopia is associated with high myopia in adult life.¹⁸ The myopia progression rate in Asian children is high (nearly -1 D/year), and approximately 24% of the population become high myopes as adults.^{11,36,37} It has become a severe public health problem. Onset of myopia typically occurs during the early years of grade school and progresses until the eye is fully grown.³⁸⁻⁴⁰ Therefore, intervention to prevent or postpone myopia onset in children may reduce the prevalence of high myopia. This study showed that the ROC program has a significant effect in preventing myopia onset and myopic shift in nonmyopic subjects of the current population. More outdoor activities and breaks in near-range visual work may be beneficial in elementary schools to decrease myopia prevalence.

The effect of age on nonmyopic and myopic subjects varied in this study. Nonmyopic subjects in higher school years had less myopia shift, possibly because subjects in lower school years had higher hyperopic refraction and faster myopic shift to emmetropia than subjects in higher school years. Among myopic children, students in higher school years had more myopic progression. This may be the result of Taiwan's educational system placing greater academic stress on students in higher school years than those in lower school years. The educational policy influences and reduces the time spent on outdoor activities, an important factor associated with myopia.²⁹

By contrast, the results showed that the ROC program had no significant effect on myopic subjects. For myopic children without atropine treatment, the ROC program reduced myopia progression, but did not reach significance when compared with the control group (-0.20 ± 0.69 D vs. -0.37 ± 0.67 D; $P = 0.125$). In this study, as many as 25% of the myopic school children received atropine treatment. Most children in southern Taiwan received a low-concentration atropine eye drop treatment.^{41,42} Among these myopic children with atropine treatment, the ROC program had little additional inhibiting effect on myopia compared with the control group (-0.28 ± 0.57 D vs. -0.31 ± 0.44 D; $P = 0.85$). Fast myopia progression in myopic children is difficult to control. Mutti et al (Mutti DO, Sinnott LT, Jones LA, et al. Time outdoors, near work, and the progression of myopia in children. Paper presented at: ARVO Annual Meeting, May 4, 2010; Fort Lauderdale) have reported that outdoor activity only reduces the risk of myopia onset; it has no major effect on its progression.⁴³ For myopic children, the present study also showed that the protective effect of outdoor activity does not retard myopia progression in myopic children.

There is some suggestion from findings in Australia, Singapore, and the United States that there may be a threshold of 10 to 14 hours spent outdoors per week required to prevent myopia.^{24,29} Lu et al⁴⁴ failed to find a protective effect of outdoor activity in a rural Chinese population with a high prevalence of myopia. The children have averaged only 6 hours outside per week, which may be below the threshold. In this study, the precise records of time spent outdoors per week by each participant were not available. Nevertheless, it could be estimated. There were different types of activities in the 2 schools during recess time. For the control arm, approximately half of the children stayed in the classroom during recess time for near work. For the intervention arm, the classrooms were emptied and all children were encouraged to participate in outdoor activities. For the children who used to stay inside the classroom during recess time, the program increased the daily amount of time spent outdoors by at least 80 minutes (6.7 hours per week). The children in the ROC group had an estimated time of 11.2 hours per week spent outdoors (6.7 hours in school recess time, 2 hours for physical education, and 2.5 hours after school). In contrast, the estimated time spent outdoors per week for the children in the control group was approximately 7.6 hours (3.3 hours in school recess time, 2 hours for physical education, and 2.3 hours after school). Although the exact threshold time for outdoor activity required to prevent myopia is still under investigation, time spent outdoors below the threshold cannot prevent myopia onset and myopic shift. In this study, if the children who already had myopia were still not spending enough time outside despite intervention or have the need for more time outdoors to prevent myopia progression, it may explain why there is no apparent effect on the rate of progression of pre-existing myopia. In addition, outdoor activities after school accounted for only fewer than 3 hours per week in this study population, and this may be far less than the threshold time to affect myopia. This also may explain why activity outside the classroom seems to be a protective factor for the myopic shift, whereas outside

activities of fewer than 3 hours after school in this study were not a statistically significant protective factor.

The ROC program provides school children with more time to spend outdoors during school. Several studies indicate that outdoor activity can be considered a protective factor against myopia,^{24,26,28,29} although the exact mechanism is still under investigation. Brighter light may be one possible mechanism to protect against myopia. Two recent animal studies have shown that high ambient lighting retards the development of form-deprivation myopia in chicks and monkeys.^{45,46} Brighter light potentially reduces the development of myopia through pupil constriction, resulting in less visual blur, or through stimulation of dopamine release—an eye growth inhibitor—from the retina.

The limitations of this study include the lack of individual randomization, the lack of subject diversity in terms of residence (individuals from suburban areas only), and the lack of precise hours in outdoor lighting for each individual. This study is a pilot interventional study to investigate the school ROC program's effect on myopic shift from 2 schools that are similar in terms of socioeconomic status. It is realistic to randomize the children in each school, but there would be a contamination effect, such as if children in the intervention group asked their friends from the control group to go outside to play together during recess time. However, further studies including a specific hypothesis; a well-designed sample size; diverse residential areas; a reduced contamination effect from a modified, randomized design; and precise time and light-intensity recording for each participant are warranted.

In conclusion, this study showed that outdoor activities during class recess have a significant effect on the control of myopia onset and myopic shift in nonmyopic children, but not in myopic children. This would point to possible directions to take for the prevention of myopia in the future.

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