# Outdoor Activity Reduces the Prevalence of Myopia in Children

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**Objective:** To assess the relationship of near, midworking distance, and outdoor activities with prevalence of myopia in school-aged children.

**Design:** Cross-sectional study of 2 age samples from 51 Sydney schools, selected using a random cluster design.

**Participants:** One thousand seven hundred sixty-five 6-year-olds (year 1) and 2367 12-year-olds (year 7) participated in the Sydney Myopia Study from 2003 to 2005.

**Methods:** Children had a comprehensive eye examination, including cycloplegic refraction. Parents and children completed detailed questionnaires on activity.

**Main Outcome Measures:** Myopia prevalence and mean spherical equivalent (SE) in relation to patterns of near, midworking distance, and outdoor activities. Myopia was defined as SE refraction ≤−0.5 diopters (D).

**Results:** Higher levels of outdoor activity (sport and leisure activities) were associated with more hyperopic refractions and lower myopia prevalence in the 12-year-old students. Students who combined high levels of near work with low levels of outdoor activity had the least hyperopic mean refraction (+0.27 D; 95% confidence interval [CI], 0.02–0.52), whereas students who combined low levels of near work with high levels of outdoor activity had the most hyperopic mean refraction (+0.56 D; 95% CI, 0.38–0.75). Significant protective associations with increased outdoor activity were seen for the lowest ($P$ = 0.04) and middle ($P$ = 0.02) tertiles of near-work activity. The lowest odds ratios for myopia, after adjusting for confounders, were found in groups reporting the highest levels of outdoor activity. There were no associations between indoor sport and myopia. No consistent associations between refraction and measures of activity were seen in the 6-year-old sample.

**Conclusions:** Higher levels of total time spent outdoors, rather than sport per se, were associated with less myopia and a more hyperopic mean refraction, after adjusting for near work, parental myopia, and ethnicity.
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Myopia is an eye condition that poses significant costs for optical correction and costs due to associated cataract[1–3] and glaucoma[4–6] in the longer term. In the latter part of the 20th century in highly urbanized East Asian regions,[7–9] the prevalence of myopia has increased dramatically and, in some highly educated groups, now exceeds 80%.[10–12] In parallel with the increase in overall myopia, there has been a rise in the prevalence of high myopia (≤−6 diopters [D]),[13] which is associated with increased levels of visual impairment and blindness,[14] primarily due to chorioretinal degeneration and retinal detachment. Furthermore, myopia is appearing with greater prevalence in young children,[13,15] which places these children at greater risk of developing high myopia, with its associated complications.

Due to these trends in the prevalence of myopia, there has been a research focus on factors that could increase the risk of myopia. It is well established that the prevalence of myopia in children is greater if their parents are myopic.[9,16–21] East Asian ethnicity has also been proposed as a possible risk factor. Although these 2 factors could indicate a genetic contribution, myopia is generally believed to have a multifactorial etiology, and the rapid rise in prevalent myopia suggests that rapidly changing environmental factors are predominant in determining the current patterns of myopia.[22]

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Because myopic refractive error tends to have its onset and increase progressively during the school years, intensive near work, particularly reading, has been hypothesized to lead to myopia.[23] Although this idea is intuitively appealing, particularly because of the obvious links between near work and accommodation, to date near work has been shown to make only a small contribution to the overall prevalence of myopia.[15,21] In addition, attempts to manipulate accommodation have not proved effective in preventing myopia,[20] except for the small group of near esophores.[24,25] Although atropine has been shown to slow the progression of myopia,[26] animal studies using atropine suggest that its effect is not through the blocking of accommodation.[27]

Using data from a large representative sample of Australian schoolchildren from 2 age samples, the Sydney Myopia Study examined a wide range of potential environmental risk factors for myopia, adjusting for the influences of parental myopia and ethnicity. We focused on the relationship between patterns of near, midrange, and distance viewing activities to examine the hypothesis that outdoor activity may play a significant role in controlling the development of refractive error, in part because of the low prevalence of myopia, by international standards, reported for Australian children[28] and adults.[29]

## Materials and Methods

The Sydney Myopia Study is a population-based survey of refraction and other eye conditions in a sample of year 1 and year 7 school children resident in the metropolitan area of Sydney, Australia. Methods used to identify and select the target sample, as well as a description of this sample and study procedures, are reported elsewhere.[28,30] In brief, the study area was stratified by socioeconomic status, using Australian Bureau of Statistics 1996 and 2001 national census data. Using this sampling frame, 34 primary and 21 secondary schools were selected across Sydney, including 5 primary and 2 high schools in the top socioeconomic status decile, with the remaining schools randomly selected from the bottom 9 socioeconomic status deciles. A proportional mix of public and private/religious schools was included.

Informed written consent from at least one parent and the verbal consent of each child were obtained before examination. Approval for the study was obtained from the Human Research Ethics Committee, University of Sydney; New South Wales Department of Education and Training; and Sydney Catholic Education Office. The project adhered to the tenets of the Declaration of Helsinki.

Children had a comprehensive eye examination, including cycloplegic autorefraction, to determine refractive status. After corneal anesthesia with amethocaine hydrochloride 1%, cycloplegia was obtained with 2 cycles of cyclopentolate 1% (1 drop) and tropicamide 1% (1 drop) instilled 5 minutes apart. Cycloplegia was considered full when the pupil was fixed and ≥6 mm in diameter. An autorefractor (model RK-F1, Canon, Tokyo, Japan) was used to perform cycloplegic autorefraction and keratometry, 30 minutes after the last administration of cycloplegic eyedrops. Spherical equivalent refractive error (SER) was calculated as sphere + ½ cylinder.

Parents were asked to complete an extensive questionnaire including questions about periods during which children engaged in a variety of near work, indoor and outdoor activities from reading to picnics and walking. For the 6-year-olds, parents, and for the 12 year-olds, the children, nominated the time spent on these activities for both weekdays and weekends, and the average daily hours spent on that activity were calculated. Responses regarding the time spent in activities were validated against a 24-hour clock for weekdays and weekends. The activities undertaken by the children were grouped into near work, midworking distance, and outdoor activities. The average hours spent in near-work activity (at <50-cm working distance) were summed from questions on drawing, homework, reading, and handheld computer use. Midworking distance activity included television watching, videogame playing, and computer use. Time spent in outdoor activities was based on questions about playing outdoors, family picnics and barbeques, bicycle riding, bush walking, and outdoor sport. Time engaged in indoor sporting activities was also estimated. Activity levels were low, medium, or high, using population tertiles of the average daily hours spent in these different activities.

In view of the diverse range of reported prevalence rates for myopia from different ethnic communities worldwide,[22] this study classified children into different ethnic groups, based on the self-identified ethnic origin of both parents. Modern population classifications based on molecular biology were modified for practical application into group names that people would readily understand in a self-identification question in the questionnaire. The classification is consistent with the Australian Standard Classification of Cultural and Ethnic Groups.[31] The groups represented in the questionnaire were European Caucasian, East Asian, South Asian (Indian, Pakistani, Sri Lankan), African, Melanesian/Polynesian, Middle Eastern, indigenous Australian, and South American. The questionnaire was translated into 3 major community languages—Chinese, Vietnamese, and Arabic.

Assessment of parental refractive error was based on prescriptions for glasses if available. Prescriptions for the worse eye were used to define refractive error. Myopia was defined as SER ≤ −0.50 D. If prescriptions were unavailable, parents' responses to questions about the viewing distance for which glasses were most frequently used and the age at first use of glasses were used. Myopia was assigned to parents who indicated that they used glasses primarily for distance viewing or if the age at first use was ≤30 years.

### Data Handling and Statistical Analysis

Data were entered into an Access database (Microsoft, Redmond, WA). All statistical analyses were performed using the Statistical Analysis System (SAS-V9.1, SAS Inc., Cary, NC). No imputations were done for missing data. All analyses were conducted using only children for whom all relevant data were available. There was no indication of selection bias, as children for whom all data were available were similar to the children with missing data in all other respects. Associations between SER and near work or outdoor activity levels were assessed using mixed models to adjust for clustering within schools, in all children and then stratified by gender, ethnic background, and parental myopia status. Activity level was first analyzed continuously as the average daily hours of activity reported, and then in population tertiles. A multivariable model was constructed to adjust for other significant demographic, parental, and activity-related factors. The joint effect of near work and outdoor activity level was assessed, using data for only those children who reported both near and outdoor measures, using mixed models for SER and logistic regression for odds of myopia. Odds ratios (ORs) and 95% confidence intervals (CIs) are presented.

Table 1. Mean Spherical Equivalent Refractive Error (SER) (Diopter) by Ethnic Group, Gender, and Parental Myopia for the Year 1 (Mean Age, 6.7 Years) and Year 7 (Mean Age, 12.7) Samples

| | Year 1 Sample | | | | Year 7 Sample | | | |
|---|---|---|---|---|---|---|---|---|
| **Characteristic** | *n* | *% Myopic* | *SER* | *95% CI* | *N* | *% Myopic* | *SER* | *95% CI* |
| All children | 1735 | 1.5 | +1.26 | 1.19–1.33 | 2353 | 12.8 | +0.49 | 0.27–0.71 |
| Ethnic background* | | | | | | | | |
| European Caucasian | 1105 | 0.7 | +1.40 | 1.34–1.45 | 1406 | 5.1 | +0.81 | 0.72–0.90 |
| East Asian | 298 | 3.4 | +0.91 | 0.85–0.97 | 352 | 41.6 | −0.50 | −0.83 to 0.18 |
| Gender | | | | | | | | |
| Girls | 857 | 1.6 | +1.34 | 1.25–1.42 | 1163 | 15.0 | +0.41 | 0.14–0.68 |
| Boys | 878 | 1.4 | +1.19 | 1.12–1.26 | 1190 | 10.7 | +0.56 | 0.40–0.72 |
| Parental myopia† | | | | | | | | |
| No myopic parents | 778 | 0.8 | +1.37 | 1.29–1.44 | 1120 | 7.6 | +0.67 | 0.52–0.81 |
| One myopic parent | 398 | 2.5 | +1.23 | 1.09–1.36 | 542 | 14.8 | +0.33 | 0.15–0.50 |
| Two myopic parents | 95 | 3.2 | +0.98 | 0.86–1.10 | 126 | 43.6 | −0.55 | −1.23 to 0.13 |

CI = confidence interval.
*Three hundred thirty-two children of other ethnic backgrounds were not analyzed.
†Four hundred sixty-four children without data on parental refractive status were excluded.

## Results

Of the 2238 eligible children in year 1, 1765 (78.9%) were given parental permission to participate and 1740 were examined. Of the 3130 eligible children in year 7, 2367 (75.3%) were given permission and 2353 were examined (Table 1). Mean ages were 6.7 years (year 1 participants; range, 5.5–8.4) and 12.7 (year 7 participants; range, 11.1–14.4). Girls comprised just under half of each sample (49.4% in year 1 and 49.4% in year 7). Ethnicity of the year 1 sample was predominantly European Caucasian (63.7%), followed by East Asian (17.2%). This was similar in the year 7 sample (European Caucasian, 59.7%; East Asian, 15.0%). In both age samples, SERs in right and left eyes were highly correlated (Pearson correlation = 0.9). Therefore, only data for right eyes are presented.

As shown in Table 1, the mean SER for the year 1 sample was +1.26 D (95% CI, 1.19–1.33) and the proportion of children with myopia was low (1.5%). Children of European Caucasian background had a mean SER of +1.40 D, and the proportion with myopia was 0.7%. These measures significantly differed ($P<0.0001$) in children of East Asian origin (mean SER, +0.91 D; myopia, 3.4%). In year 7, the mean SER for the whole sample was still hyperopic (+0.49 D; 95% CI, 0.27–0.71) but had significantly shifted towards emmetropia. The proportion of children with myopia was higher, at 12.8%. Mean SER values in the 2 ethnic groups in year 7 (European Caucasian, +0.81 D; East Asian, −0.50 D) significantly differed ($P<0.0001$), as did proportions of each ethnic group with myopia (5.1% and 41.6%, respectively). It should be noted that our random sample included 2 academic selective schools that had a higher proportion of children of East Asian origin than found in other schools. Enrollment in these schools indicates high academic achievement accompanied by high levels of near work.

In the year 1 sample, the mean SER in girls was more hyperopic (+1.34 D) than that in boys (+1.19 D). This trend was reversed in the year 7 sample, in which boys had a mean SER of +0.56 D and girls had one of +0.41 D. Compared with children who had no myopic parents, the mean SER became progressively more myopic for children who had one or two myopic parents.

### Outdoor Activity

The average time spent by children outdoors, including both outdoor sport and other activities such as playing outside, picnics, and walking, was similar for both year 1 and year 7 samples (2.32 and 2.39 hours per day, respectively). After adjustment for gender, ethnicity, parental myopia, near work, maternal and parental education, and maternal employment, a greater number of hours spent outdoors was associated with a more hyperopic mean SER in both year 1 ($P = 0.009$) and year 7 ($P = 0.0003$) students (Table 2). When hours spent on outdoor activities excluding sport were considered, the trends were highly significant (year 7, $P<0.0001$). In contrast, time spent on indoor sport had no significant effect on refractive error (year 7, $P = 0.9$).

In the year 1 sample, the trend towards a more hyperopic mean SER with increasing hours spent outside was significant only for boys ($P = 0.01$). Boys spent an average 19 minutes per day more outside than girls (2.47 and 2.16 hours, respectively). Children without myopic parents spent an average 2.46 hours outside per day, and there was no significant relationship between mean SER and hours spent outside. While children with myopic parents spent less time outside (average 2.14 hours), for these children there was a significant relationship between refraction and hours spent outside ($P = 0.0005$). Year 1 children of European Caucasian ethnicity spent an average one third more time (55 minutes) outside per day than children of East Asian ethnicity (2.49 and 1.57 hours, respectively). When the mean SER was stratified by ethnic origin, however, there was no apparent relationship of refraction to the number of hours spent outside in either group.

In the year 7 sample, a pattern of higher mean SER with increasing hours spent outside was observed overall and was significant in boys ($P = 0.003$), who spent an average 24 more minutes outside each day than girls (2.59 and 2.19 hours, respectively); the relationship approached statistical significance ($P = 0.052$). Girls in year 7 who were in the lowest tertile of hours per day spent outside, however, had a significantly less hyperopic mean SER (+0.14 D) than girls performing moderate to high amounts of outdoor activity (mean SERs, +0.51 and +0.55 D, respectively). Year 7 students with myopic parents spent an average 2.33 hours outside daily, compared with 2.46 hours for children without myopic parents. In this age group, the trend towards a more hyperopic mean SER with greater time spent outside was seen only in children whose parents were not myopic.

In year 7, children of European Caucasian ethnicity spent an average 52 more minutes per day in outdoor activity than children of East Asian ethnicity (2.62 and 1.76 hours, respectively). There was a significant trend towards a less hyperopic mean SER with less time outdoors in the European Caucasian children, whereas

Table 2. Associations between Outdoor Activity (Tertiles of Hours per Day) and Spherical Equivalent Refractive Error (SER) (Diopter)*

| Outdoor Activity (Average Hours per Day)† | Year 1 Sample | | | | | Year 7 Sample | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Trend | | | | | Trend | |
| | Low (0–1.7) (Mean SER) | Moderate (1.7–2.7) (Mean SER) | High (2.7+) (Mean SER) | β Coefficient | P Value | Low (0–1.59) (Mean SER) | Moderate (1.6–2.8) (Mean SER) | High (2.8+) (Mean SER) | β Coefficient | P Value |
| All children | +1.24‡ | +1.31‡ | +1.41 | +0.05 | 0.009 | +0.32‡ | +0.50 | +0.54 | +0.07 | <0.0003 |
| Gender | | | | | | | | | | |
| Girls | +1.37 | +1.37 | +1.52 | +0.06 | 0.09 | +0.14‡ | +0.50 | +0.37 | +0.07 | 0.052 |
| Boys | +1.10‡ | +1.26 | +1.29 | +0.04 | 0.01 | +0.54‡ | +0.48‡ | +0.68 | +0.06 | 0.003 |
| Parental myopia | | | | | | | | | | |
| None | +1.36 | +1.41 | +1.44 | +0.02 | 0.4 | +0.56‡ | +0.67 | +0.79 | +0.08 | 0.0003 |
| Any | +1.06‡ | +1.15‡ | +1.40 | +0.14 | 0.0005 | −0.05 | +0.18 | +0.18 | +0.04 | 0.2 |
| Ethnicity | | | | | | | | | | |
| European Caucasian | +1.34‡ | +1.38‡ | +1.49 | +0.04 | 0.15 | +0.70‡ | +0.80 | +0.89 | +0.06 | 0.002 |
| East Asian | +0.94 | +0.87 | +0.88 | +0.05 | 0.5 | −1.00 | −0.63 | −0.76 | +0.12 | 0.3 |

*Adjusted for gender, ethnicity, parental myopia, near-work activity, maternal and paternal education, and maternal employment.
†Includes outdoor sports, playing out of doors, and other outdoor leisure activities. Cut points are based on population tertiles for average daily hours spent outside.
‡Significant ($P<0.05$) compared with the highest tertile of activity as the reference group.

time spent outside did not significantly affect the mean SER of the East Asian children.

## Near-Work Activity

Average times spent on near-work activities, including homework, reading, handheld computer use, and drawing, were 2.29 hours in year 1 and 2.74 hours in year 7. As shown in Table 3, after adjusting for gender, ethnicity, parental myopia, outdoor activity, and other risk factors for myopia there was no overall association of near work and mean SER in the year 1 sample ($P = 0.08$), although a significant association with mean SER was observed in children whose parents were not myopic ($P = 0.004$).

In the total year 7 sample, there was no association between less hyperopic mean SER and greater levels of near-work activity, after adjusting for a range of risk factors ($P = 0.8$). Among the year 7 children whose parents did not have myopia, there was a significant difference in mean SER between those in the lowest and highest tertiles of near-work activity, even though the trend across tertiles was not significant. A trend towards less hyperopic mean SER with greater hours of near work was seen in children of European Caucasian origin ($P = 0.01$) but not in children of East Asian origin.

## Midworking Distance Activities

The influence of midworking distance activities, such as watching television, playing videogames and using computers, on refraction was also examined. In the year 1 sample, students spent an average 1.89 hours daily in these activities. This rose by nearly 1 hour per day in the year 7 sample, to 2.86 hours. However, midworking distance activities were not associated with mean SER in either the

Table 3. Associations between Near-Work Activity and Spherical Equivalent Refractive Error (SER) (Diopter)*

| Near-Work Activity (Average Hours per Day)† | Year 1 Sample | | | | | Year 7 Sample | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Trend | | | | | Trend | |
| | Low (0–1.5) (Mean SER) | Moderate (1.6–2.5) (Mean SER) | High (2.6+) (Mean SER) | β Coefficient | P Value | Low (0–<2.0) (Mean SER) | Moderate (2.0–3.1) (Mean SER) | High (3.1+) (Mean SER) | β Coefficient | P Value |
| All children | +1.35 | +1.32 | +1.28 | −0.04 | 0.08 | +0.48 | +0.48 | +0.42 | −0.007 | 0.8 |
| Gender | | | | | | | | | | |
| Girls | +1.43 | +1.45 | +1.37 | −0.03 | 0.3 | +0.29 | +0.38 | +0.32 | +0.001 | 0.9 |
| Boys | +1.28 | +1.20 | +1.19 | −0.05 | 0.07 | +0.63 | +0.56 | +0.53 | −0.02 | 0.6 |
| Parental myopia | | | | | | | | | | |
| None | +1.47‡ | +1.43‡ | +1.32 | −0.08 | 0.004 | +0.78‡ | +0.66 | +0.60 | −0.04 | 0.1 |
| Any | +1.14 | +1.15 | +1.26 | +0.03 | 0.3 | +0.50 | +0.20 | +0.11 | +0.04 | 0.4 |
| Ethnicity | | | | | | | | | | |
| European Caucasian | +1.45 | +1.41 | +1.37 | −0.04 | 0.14 | +0.91‡ | +0.82 | +0.69 | −0.06 | 0.01 |
| East Asian | +0.71 | +0.92 | +1.02 | +0.04 | 0.3 | −1.18 | −0.69 | −0.82 | +0.15 | 0.06 |

*Adjusted for gender, ethnicity, parental myopia, outdoor activity, maternal and paternal education, and maternal employment.
†Includes drawing, homework, reading, and handheld computer use.
‡Significant ($P<0.05$) compared with the highest tertile of activity as the reference group.

Table 4. Multivariable-Adjusted Mean Spherical Equivalent Refractive Error (SER) (±95% Confidence Intervals) (Diopter)* by Reported Average Daily Hours Spent on Near-Work versus Outdoor Activities in 12-Year-Olds

| | | Near-Work Activities‡ | | | |
|---|---|---|---|---|---|
| | **Overall Average Daily Activity Reported†** | *Low (0–1.99 hrs) (N = 752)* | *Moderate (2–3.1 hrs) (N = 719)* | *High (3.1+ hrs) (N = 721)* | **P Value for Trend** |
| Outdoor activities§ | Low (0–1.59 hrs) (N = 687) | +0.33 (0.06–0.59) | +0.40 (0.24–0.57) | +0.27 (0.02–0.52) | 0.7 |
| | Moderate (1.6–2.8 hrs) (N = 738) | +0.52 (0.37–0.67) | +0.50 (0.36–0.64) | +0.48 (0.20–0.77) | 0.9 |
| | High(2.8+ hrs)(N = 767) | +0.56 (0.38–0.75) | +0.54 (0.44–0.64) | +0.52 (0.32–0.71) | 0.9 |
| *P* value for trend | | 0.04 | 0.02 | 0.06 | *P* value for interaction, 0.7 |

*Adjusted for gender, ethnicity, parental myopia, parental employment, and education.
†Cut points define population tertiles.
‡Includes drawing, homework, reading, and handheld computer use.
§Includes outdoor sport, playing out of doors, and other outdoor leisure activities.

year 1 ($P = 0.7$) or the year 7 ($P = 0.8$) sample. Addition of hours performing indoor sporting activities did not alter the lack of association with mean SER for either year 1 or year 7 students ($P = 0.9$ for both age samples).

## Combined Effect of Outdoor Activity and Near Work

The possibility that varying levels of outdoor activity and near work could interact to influence refraction was examined in a 2-way analysis in the year 7 sample, shown in Table 4. After adjustment for gender, ethnicity, parental myopia, and parental employment and education, there was a significant trend towards more hyperopic mean SER, with increasing tertiles of outdoor activity for the low and moderate tertiles of near-work hours. This trend approached significance for the highest level of near-work activity. However, there was no significant association between tertiles of near work and refraction, for any tertile of outdoor activity. In similar analyses of the year 1 sample, no significant associations between mean SER and tertiles of near work and outdoor activities could be demonstrated after adjusting for other factors.

The combined effects of outdoors and near-work activities on the odds for myopia are explored in the year 7 sample in Figure 1.

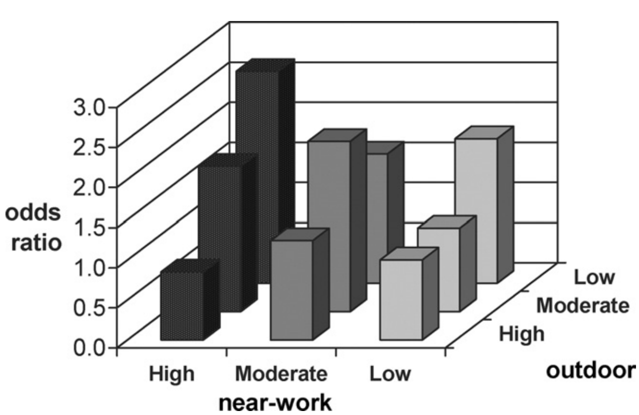


**Figure 1.** Multivariable-adjusted odds ratios (adjusted for gender, ethnicity, parental myopia, parental employment, and education) for myopia by reported average daily hours spent on near-work versus outdoor activities in 12-year-olds. Activities were divided into tertiles of high, moderate, and low levels of activity. The group with high levels of outdoor activity and low levels of near work is the reference group.

Children with high outdoor and low near-work activity levels were used as the reference group (OR, 1). Children with low outdoor and high near-work activity had 2- to 3-fold higher odds for myopia than the reference group (OR, 2.6; 95% CI, 1.2–6.0; $P = 0.02$). The stepwise pattern of increase in risk of myopia with reduced levels of outdoor activity appeared stronger and more consistent than the effects of near work. Consistent stepwise patterns were not found in analyses of children of European Caucasian ethnicity, although ORs for myopia were consistently lower in groups reporting the highest levels of outdoor activity and in groups performing the lowest levels of near work. There was little correlation between hours of outdoor activities and hours of near work (6 year olds, $r = 0.20$; 12 year olds, $r = 0.03$) or hours of midworking distance activities (6 year olds, $r = 0.15$; 12 year olds, $r = 0.14$).

## Discussion

Although some previous studies have reported an association between refractive error and more time spent on sport or outdoor activities, this population-based study is the first to make separate detailed measurements of time spent on outdoor activities and engagement in near work and indoor activities, which enable a discrimination between the effects of near work, middistance, and distance activities, as well as the effects of time spent on sport and total time spent outdoors.

Parssinen and Lyyra[32] reported gender-specific associations of sport and outdoor activities with myopia, with no association in girls and an association between increased time spent on sport and outdoor activity and less myopia in boys. Mutti et al have reported a protective effect against myopia of engagement in sports and outdoor activities, in both a cross-sectional study[21] and, more recently, a longitudinal study,[33] whereas protective effects of sport have been reported for children in Jordan[34] and for time spent outdoors as a child for medical students in Turkey.[35] We have recently reported that differences in time spent on outdoor activities contribute significantly to the marked differences in the prevalence of myopia in age-matched children of Chinese ethnicity growing up in Singapore and Sydney.[36] Our findings suggest that being outdoors, rather than sport per se, may be the crucial factor, because the association between increased outdoor hours and lower myopia was found even if time spent on outdoor sport was not included, and time spent on indoor sports had no effect.

The most myopic mean SER was seen in the students who combined high levels of near work with low levels of outdoor activity, whereas the most hyperopic mean SER was seen in those who combined low levels of near work with high levels of outdoor activity. An apparent protective effect from higher levels of outdoor activity was seen across the tertiles of near-work activity. Similarly, the lowest OR for myopia, after adjusting for relevant factors, was seen in the groups reporting high levels of outdoor activity, independent of the level of near-work activity.

The effects of near work and associated factors on refractive error have been extensively investigated and, while often observed, have not been consistent or strong.[15,21] In our study, there was no significant influence of near work on refractive status in the entire year 7 sample, after adjusting for many likely confounders, but there was a significant trend for the European Caucasian children alone. Midworking distance activities, also performed indoors, showed no significant association with mean SER.

The impact of outdoor activities needs to be explained. One possibility is that high engagement in outdoor activities could simply preclude high engagement in near-work activities and midrange activities—a substitution effect. This explanation is unlikely to be correct, because near-work and midworking distance activities appeared to have little, if any, impact on refraction, so that simple substitution should equally have little impact. Further, we found little correlation between hours of outdoor activities and hours of near work or hours of midworking distance activities. Furthermore, the effects of increased outdoor activities on spherical equivalent refraction were clearly evident within each tertile of near-work activity.

Given that physical activity or sport does not appear the critical factor, one possible hypothesis for the effect of outdoor activities on refraction is related to the low accommodative demand in distance vision. Although this is commonly postulated, it seems unlikely to be an important factor because, for practical purposes, viewing objects at 6 m is optically equivalent to viewing objects at infinity. It is unlikely that a biological mechanism for controlling eye growth could be based on the minimal accommodative requirements for focus beyond 6 m. Further, an emmetropic eye focused on distant objects would be subject to hyperopic blur for nearby objects, and because work on animal models suggests that hyperopic blur promotes eye growth, this would be expected to promote rather than inhibit myopia.[37]

We suggest that light intensity may be an important factor. Light intensities are typically higher outdoors than indoors, and pupils will be more constricted outdoors. This would result in a greater depth of field and less image blur. Alternatively, release of dopamine from the retina is known to be stimulated by light, and dopamine can act as an inhibitor of eye growth.[38] These hypotheses need to be systematically tested but may provide an explanation of the particularly low prevalence of myopia reported for both children and adults in Australia, as compared with ethnically matched peers in other countries.[28,29]

The apparent protective effect of time spent outdoors suggests that a public health measure aimed at preventing development of myopia could be based on increasing the engagement of children in outdoor activity. Promoting outdoor activity could be encouraged by devising strategies to encourage parents and families to engage their children in a variety of outdoor pursuits, including sport, and by including more outdoor activity in school curricula. This message is also compatible with the public health message on the importance of physical activity in relation to childhood obesity.

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