

Literature Review

Outdoors Activity as A Protective Factor of Myopia Incidence in Children

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ABSTRACT

Background: Outdoors activities emerge as one of protective factors in myopia incidence and progression. The aim of this literature review is to evaluate the effect of outdoor activity on prevention of myopia incidence in children age 0 to 18 years old.

Methods: The literature search was conducted from MEDLINE database using Pubmed for journal articles that were published and related to the association between outdoor activity and incidence of myopia, guided by MOOSE checklist. Random effect meta-analysis is done on 1 hour/week outdoor activity and incidence of myopia.

Results: Thirteen studies were reviewed, 8 of which are cross-sectional studies and 5 of which are cohort studies. Random effect meta-analysis showed OR of 0.9 (CI 95% 0.59-1.55).

Conclusion: Outdoor activity as protective factor in preventing incidence of myopia is still inconclusive. However, throughout most articles reviewed in this literature, there is a trend towards its protective effect in preventing myopia incidence.

Myopia (short-sightedness or near-sightedness) arises from a mismatch between the axial length of the eye and the focal power of its refractive elements, producing blurred distance vision.¹ The prevalence of myopia in school-aged children varies significantly between populations living in a different location.² Prevalence of myopia in Western countries was reported 25-50% among young adults, and up to 80% in parts of South East Asia.¹ In Indonesia, Barliana et al,³ reported 52.78% prevalence of myopia among schoolchildren in urban area and 20.24% among schoolchildren in rural area. Another studies done by Nasarudin et al⁴ and Sari et al⁵ reported prevalence of myopia 17.4% and 18.7% respectively.

Refractive status is a complex variable, determined by the balance of the optical power

of the cornea and the lens, and the axial length of the eye. The axial length is the most variable factor during development, with strongest correlation with refractive status. Control of axial elongation of the eye during development is therefore crucial for achieving normal vision.⁶ Various hypothesis emerge as factors contributing to incidence of myopia, such as near work during childhood,⁷⁻¹² urban versus rural living,^{10,13,14} level of education,¹⁵ educational performance,¹⁶ parental myopia^{2,17} and outdoor activity.^{1,8,9,13,14,18-23} Outdoors activities emerge as one of protective factor in myopia incidence and progression. It is postulated that increased light intensity outdoors might protect from myopia because of increased release of retinal transmitter dopamine, which is known to reduce eye growth

in experimental myopia. A role of vitamin D has also been suggested, but still lacking evidence.⁶

A strategy to prevent incidence of myopia in children is needed. A minimally invasive intervention that is currently research as preventive measure of myopia is promotion of outdoor activity.²⁴ Encouragement of outdoor activity for children can be a strategic method to control myopia incidence in children.²⁵ Other include optical interventions such as usage of simple correction, bifocal lens, progressive addition lenses, and overnight orthokeratology contact lenses,^{26,27} and medical intervention include usage of atrophine eye drop.²⁸⁻³²

Myopia that is not fully corrected is major cause of visual impairment recognized by WHO.³³ Thus, promotion of outdoor activity for children can be an efficient and strategic method to control myopia incidence in children.²⁵ However, evidence is still varies, and therefore important to review preventive effect of outdoor activity on myopia systematically. The aim of this literature review is to evaluate the effect of outdoor activity on prevention of myopia incidence in children age 0 to 18 years old.

MATERIAL AND METHOD

Data Source

The literature search was conducted from MEDLINE database using Pubmed for journal articles that were published and related to the association between outdoor activity and incidence of myopia, using the keywords: (myopi*OR "myopia" OR "short-sight" OR "short-shighted" OR "short-sightedness" OR "short sight" OR "short sighted" OR "short sightedness" OR "near-sight" OR "near-sighted" OR "near-sightedness" OR "near sight" OR "near sighted" OR "near sightedness" OR "refractive errors" OR refract*) AND (outdoor* OR outside OR "leisure activities" OR sport* OR "physical activity" OR "motor activity" OR hobb*). The search was limited to articles published in English language. If the full text articles were not available online, manual search in the Central Library and Department of Ophthalmology Library Faculty of Medicine Universitas Indonesia were then conducted. Reference list from the included studies were also checked for potentially relevant articles.

Study Selection and Criteria

In the initial screening, journal titles and summary were reviewed to choose articles related to the study purpose based on the keywords. If consider related to study purpose, full-length articles were retrieved. Reference list from the studies were also examined. From the full-length articles, the studies were required to meet the following inclusion and exclusion criteria. Inclusion criteria were: 1) reported time spent outdoors in keeping with exposure definition; 2) reported myopia incident as the outcome measure; 3) reported a measure of the association as an effect estimate with 95% confidence interval (CI) for cross-sectional studies; 4) were limited to children aged 0 to 18 years old; 5) level II-IV according to Oxford Centre for Evidence-Based Medicine 2011 Level of Evidence.³⁴ Restriction of publication date was not performed. We excluded studies without a precise definition of myopia, full-length text could not be retrieved, and studies not published in English.

All studies that met the inclusion criteria were rated according to the level of evidence developed by Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence.³⁴

Data Processing and Presentation

To appropriately report the literature review, we were guided by the MOOSE checklist.³⁵ For each study, the following characteristics were extracted: 1) last name of first author; 2) year of publication; 3) study design; 4) area of the study population (East Asian versus not East Asian); 5) number of subject in study; 6) participation rates; 7) age range of study subjects; 8) definition of time spent outdoor; 9) definition of myopia; 10) effect estimate plus 95% CI or SE; 11) which confounding factors were adjusted for; 12) the latitude of the study location. If not presented in the original report, information on latitude was retrieved using an online resource. The primary outcome of this review is effect estimate plus 95% CI or SE from studies, showing association between outdoor activities and incidence of myopia.

RESULT

Using the searching strategies mentioned above, we found 3066 articles related to the search term. Thirty-two articles undergone full text reviewed, and only 15 were enrolled to the literature review. Seven studies were excluded because it didn't address the right research question, 1 study was not available in English, and 9 studies did not meet inclusion criteria. Data character of the literature reviewed are presented in table 2. Reviewed articles were published between 2002-2013. The studies are categorized in level III-IV based on level of evidence, 8 of which were cross-sectional studies, and 5 were cohort studies. Age distribution is between 0-18 years old. The duration of follow up for cohort studies were 3 to 15 years.

Total numbers of participants from all reviewed articles are 29,301 children, with the highest number of participant coming from study by Guggenheim et al¹, a birth cohort study of Avon Longitudinal Study of Parents and Children with 13,988 participants. Two out of thirteen studies reported was done on East Asia (Singapore), while nine other studies was done on United state, China, Taiwan, Australia, and Jordan. Six studies that were done in Singapore, China and Taiwan have participants who were mostly of Chinese ethnicity. Study with the highest incidence of myopia is the one done by Lu et al¹⁰ in Xinchang, China with 83.10% of myopia, while the lowest incidence of myopia found in study by Low et al⁹ in Singapore children age 6-72 months with only 9.97% cases of myopia.

Table 1. Individual study estimates the association of time spent outdoor with incidence of myopia in 9 cross-sectional studies

Author	Incidence of Myopia	Unit of Exposure	Time Spent Outdoor by Myopes (Mean(SD))	Time Spent Outdoor by Non Myopes (Mean(SD))	OR (95%CI)	Covariate Adjusted
Lu et al ¹⁰	83.10%	h/w	6.0(5.4)	6.2(5.9)	1.14(0.69-1.89)	Age, sex, parents education, near-work analysis
Low et al ⁹	9.97%	h/d	0.77(1.06)	0.86(1.22)	0.95(0.85-1.07)	Age gender height time spent reading words or picture alone outdoor activity parental myopia
Deng et al ¹⁸	22.45%	h/w	school year 8.25(6.24), summer 19.41(14.57)	school year 10.95(5.95) †, summer 22.44±13.56†	school year 0.915 (0.843-0.994)*, summer year 1.00 (0.969-1.033)	Age, number of myopic parents
Guo et al ¹³	N/A	h/d	N/A	N/A	0.32(0.21-0.48)*	Age, region of habitation, maternal myopia
Wu et al ³⁸	31%	two groups; "often" and "seldom or none"	often 28(29.8%), seldom or none 17(33.3%)	often 66(70.2%), seldom or none 34(66.7%)	0.3(0.1-0.9)*	school year, gender, myopic parent, reading/writing, computer, near work (other), television ethnicity, region, parental myopia, near work, age, sex, parental myopia
Ip et al ¹⁴	region 1 to 5 (outter suburban - inner city) 6.9%, 11.7%, 9.7%, 18.0%, 17.8%	h/w	N/A	N/A	0.96 (0.95-0.98)*	Family history
Khader et al ³⁷	17.60%	h/d	1.87(2.33)	4.04(2.82)*	0.89(0.86-0.93)*	Parental myopia, diopter-hours per week, ITBS subsets
Mutti et al ¹¹	18.30%	h/w	7.4(6.7)	9.7(6.2)*	0.936(0.892-0.983) (univariate)*, 0.917(0.864-0.974) (multivariate)*	

Definition of time outdoors used in these studies varies, some reported only time spent playing sport, some studies also counted general and leisure activity done outdoors. In studies conducted by Guggenheim et al¹, in England, a subtropical country, time spent outdoors measurement is differentiate between summer and winter. Deng et al¹⁸, also differentiate time spent outdoors between weekdays and weekend, and make adjustment on the mean time outdoors being used on data analysis. Unit of measurement of time spent outdoors also differs between studies, some use hours per week or day, and some use categorical variable such as low versus high, or often versus seldom to none.

Definition of myopia and measurement of refractive status also varies between studies. Most studies use cycloplegic autorefractometer to assess refractive status. Study by Deng et al¹⁸ use non-cycloplegic distance retinoscopy,

while study by Khader et al³⁷ use self-reporting of myopia, which then was crosschecked to patient's medical record. Definition of myopia used in these studies varies between SE <-0.5 D to SE ≤-1.00 D. The most commonly used definition is SE ≤-0.50 D, studies that is not using criteria mostly stated that adjustment are made due to prevent error in measurement by the autorefractors machine being used.

Study estimate on the association between outdoors activity and myopia from cross-sectional studies are listed in table 3. Mean time spent outdoor by myopes are found lowest in study by Lu et al¹⁰ with 6.0(5.4) hours per week, while found highest in study by Deng et al¹⁸ in summer with 19.41(14.57) hours per week. Mean time spent outdoors in non-myopes was found lowest in study by Low et al⁹ with 0.86(1.22) hours per day, and the highest was found in study by Khader et al³⁷ with 4.04(2.82) hours per day.

Table 2. Individual study estimates the association of time spent outdoor with incidence of myopia in 5 cohort studies

Author	Incidence of Myopia	Unit of Exposure	Time Spent Outdoor by Myopes (Mean(SD))	Time Spent Outdoor by Non Myopes (Mean(SD))	P (Uni-variate)	Effect Estimate (95%CI)	P (Multi-variate)	Covariate Adjusted
French et al ⁴⁰	14.35% in younger cohort; 17.26% in older cohort; total 12.02%	h/w	Younger cohort 20.96; Older cohort 19.62	Younger cohort 16.29; Older cohort 17.15	Younger cohort <0.0001; Older cohort 0.001	N/A	N/A	N/A
Guggenheim et al ¹	2.5% (age 7), 7.0% (age 10), 8.8% (age 11), 11.9% (age 12), 17.3% (age 15)	High vs low in winter and summer	N/A	N/A	N/A	RR 0.66 (0.56-0.78) P<0.001		Number of myopic parents, time spent reading, sex, physical activity
Jones et al ²¹	21.60%	h/w	11.65±6.97	7.98±6.54	<0.001	OR 0.91 (0.87-0.95)	<0.0001	Parental myopia
Jones-Jordan et al ³⁹	20.30%	h/w	Subject who became myopic have fewer outdoor/sport activity hours by emmetropes by 1.1 to 1.8 h/w at 4 years before onset		Significant (P not mentioned)	N/A	N/A	N/A
Saw et al ³⁶	38.8% (age 9), 41.5% (age 8), 51% (age 7)	h/d	N/A	N/A	N/A	RR 1.01(0.98-1.04)	N/A	N/A

Six out of eight studies shows significant negative association between outdoor activity and incidence of myopia. Out of these studies, the lowest OR came from study done by Wu et al³⁸ with 0.3(0.1-0.9), and highest OR from study done by Ip et al¹⁴ with 0.96(0.95-0.98). Study by Low et al⁹ shows insignificant negative association (0.95(0.85-1.07)) between time spent outdoors and myopia, while study by Lu et al¹⁰ show positive association (1.14(0.69-1.89)) but was statistically insignificant.

Summary of cohort studies in this literature review are listed in table 4 and 5. There are 5 cohort studies reviewed, one of which is a birth study done in Avon, England. Number of participants in these studies range from 731 to 13,988 patients, with follow up studies range from 3 to 15 years. Studies by French et al², Guggenheim et al¹, Jones et al²¹, and Jones-Jordan, et al³⁹ shows association between time spent outdoor with incidence of myopia, while study by Saw et al in Singapore show no relationship between outdoor activity and incidence of myopia.

French et al² stated that less time spent outdoor by children predicted greater risk of myopia, especially in younger children under 13 years old. Guggenheim et al¹ stated that time spent outdoors was predictive of incident myopia independently of physical activity level, a statement that is still being debated widely in the field of myopia. Jones-Jordan, et al³⁹ stated that outdoor exposure may exert a stronger influence on development than near-work. Most studies have the same limitation, which is the low number of exposure assessment and recall bias from questionnaire.

DISCUSSION

Myopia is thought to be multifactorial, to date various hypothesis has emerged as factors contributing to incidence of myopia, such as near work during childhood,⁷⁻¹² urban versus rural living,^{10,13,14} level of education,¹⁵ educational performance,¹⁶ parental myopia^{2,17} and outdoor activity.^{1,8,9,13,14,18-23} Outdoors activities show promising result as protective factor for myopia incidence and progression.

It is postulated that increased light intensity outdoors might protect from myopia

because of increased release of retinal transmitter dopamine, which is known to reduce eye growth in experimental myopia.⁶ A role of vitamin D has also been suggested, but still lacking evidence.⁶ One of the studies in this topic is done by Mutti et al,²³ in 2011 studied blood level of vitamin D in teens and young adults with myopia, but in his study shows insignificant difference in time spent outdoors between myopes and non myopes. If adjusted for differences in the intake of dietary variables, myopes appear to have lower average blood levels of vitamin D than non myopes.²³

The association between myopia and time spent outdoors has been widely studied recently for its promising protective effect in preventing myopia incidence. The need of finding an effective strategy to halt myopia incidence and progression is what driving these studies. In this literature review, we discuss 13 studies; 8 cross sectional studies and 5 cohort studies. Overall, 11 out of 13 studies we discuss in this paper shows negative correlation between myopia and outdoor activity. This is comparable to meta-analysis done by Sherwin, et al,⁴¹ which shows pooled OR of 0.98(0.973-0.009) on association between time spent outdoors and myopia.

Two of the article studied, Low et al and Saw et al, was carried out in East Asia, more specifically Singapore. Although being reported as country with the highest prevalence of myopia, study by Low et al⁹ shows the lowest incidence of myopia, with only 9.97%. This is probably due to the early measurement of sample (sample age 0-72 months). Another study done by Saw et al³⁶ in grade 1 to 3 children, participant of Singapore Cohort Study Of Risk Factors for Myopia (SCORM), shows myopia incidence by 45.7%. Study by Dirani et al²⁰ on the same research population between children age 11-20 shows even higher incidence of myopia with 69.5%, higher compared to any other studies being reviewed. This result suggest that the lower incidence of myopia reported in studies reviewed is due to the early measurement of refractive status of patients, and accentuate the importance of choosing the right checkpoint in conducting studies regarding risk factor of refractive status changes in children.

From latitude of studies, only two studies by Low et al⁹ and Saw et al³⁶ are conducted in tropical country, both done in Singapore. The rest of the studies are conducted in various subtropical countries. This differentiation is important because day length shows positive effect on eye growth and myopia progression. Eye elongation seem to decrease in periods with longer days and to increase in periods with shorter day. Therefore, children should be encouraged to spend more time outside during daytime to prevent myopia.⁴²

Since most studies measure time spent outdoors with questionnaire, studies that conducted in subtropical countries is more prone to recall bias, with assumption that patient will spent more time outdoor in summer than they do in winter. Timing of questionnaire and types of question will bring different result on measurement. Among all studies reviewed, only two studies differentiate measurement of time spent outdoors in winter and summer, done by Guggenheim et al¹ in Avon, England and Deng et al¹⁸ in the United State. Guggenheim et al¹ classified time spent outdoor as high if patient spent >3 hours per day, and low otherwise in summer, and low if none to less than 1 hour and high otherwise in winter. Unfortunately in their report the detail of time spent outdoor between myopes and non-myopes are not disclosed. Deng et al¹⁸ report mean time spent outdoor of 8.25 hours per week in school year and 19.41 hours per week in summer for myopes, and 10.95 hours per week in school year and 22.44 hours per week in summer for non myopes. Acknowledgement to the risk of bias in measuring time spent outdoors will allow better reporting.

One of the variables that varies between articles studied here is the definition of time spent outdoors, some studies asked only total outdoor activities without further describing the types of activities, other differentiate between time spent outdoor in general and sport activity, while other study asked only time spent playing sport. This difference brings about a question that constantly debated in every paper discussing outdoor activity association with myopia; is being outdoor and exposure to bright light is the main factor contributing to this protective effect, or is it the physical activity.

Jones et al,²¹ and Jones-Jordan et al³⁹ reported outdoor activity as “sport/outdoor activity” in association with myopia incidence in their studies. Guggenheim et al,¹ conduct a study using actigraph accelerometer to measure physical activity of participants. Two kinds of measurements are taken; mean CPM (counts per minute) for whole week, and MVPA (minutes of vigorous physical activity) per day. They conclude that the previously reported link of sport/outdoor activity and incident myopia is due mainly to its capture of information relating to time outdoor rather than physical activity.¹

Another study that supports this hypothesis was one done by Rose et al¹⁹ in Sydney Myopia Study (SMS). Rose et al¹⁹ used questionnaire that differentiate between time spent outdoors for sport, leisure and general activity. This questionnaire also assessed time spent on indoor sport. There was no association between time on indoor sport and myopia, but there was a clear protective association for both time outdoors on leisure activity and time on outdoor sport, with a particularly strong association for total time outdoors.¹⁹ Sport does not appear to be important in protecting against myopia, although clearly one way of encouraging children to spend more time outdoors is through increased participation in outdoor sport.⁴⁰

One of the issues in studies regarding myopia and time sent outdoors is the method used in quantifying time spent outdoors. All of the studies being reviewed here use questionnaire. The limitation of questionnaire is the possibility of recall bias. This has been clearly shown in study by Jones-Jordan et al,³⁹ in which 44 data were excluded because overreporting of time spent on five activities that is being asked in questionnaire.³⁹ At present, none of the questionnaire being used have been well validated. Continuing the use of these questionnaires, however, can be justified because these instruments have provided consistent evidence.⁴⁰

An alternative form of measuring time outdoor can be achieved using UV-autofluorescence (UVAF), studied by Sherwin et al.⁴³ Although animal studies has proven that it is not the ultraviolet (UV) rays but instead bright light that give protective effect on myopia,⁴⁴

measurement of UV can give objective measure of bright light (sun) exposure outdoor.⁴⁰ This method, however, has only been established in adults and has never been used to measure outdoor activity and its association with myopia. Another alternative is using HOBO light sensor and data loggers, which can measure daily illuminance, done by Schmid, et al in 2013.⁴⁵

There are also some discussion arise about substitution effect of outdoor activity, suggesting that the protecting effect of high outdoor activity maybe due to consequently decreased near work activity. In studies conducted by Mutti et al,¹¹ Rose et al,¹⁹ Ip et al,¹⁴ and Saw et al,³⁶ near work only a weak risk factor for the development of myopia. This contradict with result from study done by Guo et al,¹³ that showed strong negative association between myopia and time spent indoor/studying. A study by Rose et al,¹⁹ however, showed that after adjusting to relevant factors, myopia is associated with high level of outdoor activity independent of the level of near-work activity.

Study about the association of outdoor and incidence of myopia in Indonesia has also been conducted by Sari et al⁵ in 2010 on 910 primary schoolchildren in Tangerang county. Sari et al⁵ found medium value time spent outdoor of 7 hours per week for myopes and 9 hours per week for non myopes. Logistic regression done in this study shows that outdoor activity ≥ 7.5 hours per week compared to <7.5 hours per week had an OR of 0.640(0.045-0.922) with p value of 0.017. This result conclude that outdoor activity is a myopic protective factor.⁵

Wu et al,²⁴ in Taiwan, conducted one prospective interventional study on this matter. They implement a recess outside the classroom (ROC) program, that encourage children to go outside for outdoors activities during recess, and measure refractive status at the beginning and after 1 year, comparing with other school as control. After one year, Wu et al,²⁴ found that onset of myopia is lower in school with ROC program compared to control group, 8.41% and 17.65% respectively ($p < 0.001$). Myopic shift is also found to be lower in school with ROC program compared to control, -0.25 D/year and -0.83 D/year respectively ($p = 0.029$). Wu et al,²⁴

conclude that outdoor activities during class recess in school have a significant effect on myopia onset and myopic shift.²⁴

CONCLUSION

The limitations of this review are the limited number of study being reviewed, and high variation in variables being analyzed, such as the definition of myopia, refractive status measurement method, and the definition of outdoor time used in articles. It is also noted that most studies being reviewed are cross sectional studies, which lack ability to determine temporality of exposure and outcome. This article review shows protective effect of outdoors time in preventing incidence of myopia. However, further study on this field with better method and larger participant in Melayu ethnicity is needed. A prospective interventional study may be beneficial in further describing the effect of outdoor activity and prevention of myopia incidence. Outdoor activity as protective factor in preventing incidence of myopia is still inconclusive. However, throughout most articles reviewed in this literature there is a trend towards its protective effect in preventing myopia incidence. A prospective study also confirms that encouragement of outdoors activity in children shows protective effect in preventing myopia incidence and slowing myopic shift. The protective effect of outdoors activity in children still need to be further assessed with better study method with a favor in prospective study. An evidence of protective factor of outdoor activity and myopia in Indonesian children can be a foundation for us to advise pediatric patient to spend more time outdoor, and can be used as a base to recommend a program encouraging outdoor activities in school.

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