Article • The Influence of Near Work and Time Spent Outdoors on Refractive Error and Axial Length in Indian Children

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ABSTRACT

Background: Myopia is a complex, multifactorial disorder with interplay between genetic and environmental factors. Less time spent outdoors and increased near-work are the potential environmental risk factors for myopia. No study so far has examined the associations between time spent on near work and outdoor activity on myopic refractive error and axial length in Indian children.

Methods: 151 subjects aged 10 to 17 years were enrolled. Subjects were divided into myopes (SER: -0.50 D or more) and non-myopes (SER: -0.25 D to +2.OO D). Refractive error was measured objectively by retinoscopy with and without cycloplegia, and axial length was measured using an A-scan biometer. Near work and outdoor activities were assessed using a validated questionnaire.

Results: Subjects were divided into four groups based around their near work, using an 18-diopter hour (Dh)/day cut-off, and their outdoor activity time, with a 1-hour/day cut-off (Less Near work More Outdoor; Less Near work Less Outdoor; More Near work More Outdoor; More Near work Less Outdoor). A statistically significant interaction ($p<0.05$) was shown with near work activity and outdoor time for both refractive error and axial length. The group with more near work and less time spent outdoors showed significantly ($p<0.05$) more myopia and longer axial length compared to the group who spent less time on near work and more time outdoors.

Conclusion: Children who spent more time on near work and less time on outdoors had significantly more myopic refraction and longer axial length compared to those who performed less near work and spent more time outdoors. Our study highlights the importance of reducing near work and increasing outdoor activity in order to reduce the risk of myopia.

Keywords: axial length, children, interaction, myopia, near work, outdoor time

Introduction

Myopia has emerged as a global public health problem, especially in the East Asian countries. The prevalence of myopia is estimated to rise from 2 billion people in 2010 to 5 billion people by 2050, with about 1/5th at risk of developing sight-threatening complications due to pathologic high myopia.[1] By 2050, 50% of the global population is predicted to be myopic, with about 10% being highly myopic.[2] The increasing prevalence of myopia is a huge public health burden since progressive high myopia in children can potentially lead to vision-threatening ocular complications, low vision, and blindness.[1,3] It also poses a huge socio-economic burden due to high costs related to spectacles, contact lenses, refractive surgery, and life-long ophthalmic care.[4] Thus, prevention of early-onset myopia from progressing to pathological high myopia is of utmost importance.

Both genetic and environmental factors play a role in the etiology of myopia. Near work has been shown to be an important environmental factor associated with myopia, but recent evidence also suggests that time spent outdoors is another modifiable environmental risk factor for myopia prevention.[5-10] Previous cross-sectional and cohort studies have shown a significant association between reduced levels of myopia and outdoor activity among Australian, Singapore Chinese, Taiwanese, and Caucasian children.[11-16] Studies have also shown that reduced time spent outdoors will significantly increase the risk of myopia and its progression.[5,9,17-20]

Several population-based epidemiological studies have assessed the prevalence and incidence of myopia in urban as well as rural parts of India.[21-25] The prevalence of myopia was reported as 7% among urban children[21] and about 4% in rural children more than a decade ago.[22,23] However, a 2015 study[24] reported much higher levels of myopia (13%) among urban children. The study also reported an inverse association between myopia and time spent outdoors, with lower odds of myopia in children who spent greater than 14 hours per week outdoors.[24] A recent study has reported a protective association between myopia progression and time spent outdoors, with reduced myopic shift in children who spent greater than 2 hours per day outdoors.[25] However, the impact on myopia of both excessive near work and reduced time spent outdoors was not reported. With the recent increased rise in prevalence of myopia in India, it is important to identify any interaction between these two modifiable risk factors, near work and time spent outdoors, on an Indian population in order to develop effective intervention strategies.

This study aims to examine whether there is any interaction between time spent on near work and outdoor activity on myopic refractive error and axial length in Indian children.

Methods

Subjects

151 subjects aged 10-17 years were enrolled in the study. Participants were recruited from an outpatient clinic of a tertiary eye care hospital that mainly caters to the needs of patients with refractive errors and age-related cataracts. Children attending the outpatient clinic for primary eye care services only, such as routine eye examination and annual refractive error monitoring, were invited to participate in the study. Myopia was defined as a refractive error of at least -0.50 D or more in both principal meridians. Non-myopes were recruited through a school screening, and eligible subjects were invited to participate in the study. Subjects with spherical equivalent refractive error between -0.25 D and +2.00 D were recruited as non-myopes. Subjects with astigmatism of more than 2.00 D, binocular vision anomalies, pseudomyopia, amblyopia, keratoconus, syndromic myopia, and other ocular pathologies were excluded from the study.

Myopic family history was classified as the presence of myopia of at least -0.50 D in both principal meridians in at least one parent and/or sibling. This was determined using the following methods: (i) for parents/siblings without a medical record, refractive status was determined from the previous spectacle prescription or by checking the spectacles of the parents and siblings using a focimeter; (ii) for parents with a medical record, the prescription was ascertained from the latest eye examination, which was within the past six months to one year; (iii) when neither a medical record nor a previous spectacle prescription were available, a refraction test was performed to check the refractive status of the parent.

Ethical approval was obtained from the institutional Research and Ethics Committee. The tenets of the Declaration of Helsinki were observed. Informed consent was obtained from the parents of all participants.

Measurement of Refractive Error

All subjects underwent a baseline vision assessment using a Bailey-Lovie logMAR chart after objective and subjective refraction. Cycloplegia was achieved by instilling two drops of 1% cyclopentolate hydrochloride and one drop of 1% tropicamide, with the drops being administered in 5-minute intervals and the refraction performed after 30 minutes. Refractive error was measured objectively by retinoscopy (WelchAllyn) with and without cycloplegia. The spherical end-point criterion of maximum plus or minimum minus for best visual acuity was determined for all subjects during subjective refraction, which was then confirmed by a duochrome test.

Ocular Biometry

Corneal curvature was measured using a one-position keratometer (ShinNippon Model). An average of three readings was used. Axial length was measured using an A-scan biometer (TomeyAL, 2000), which has an accuracy of 0.1 mm and a resolution of 0.01 mm (Tomey manual, 2010). One drop of 0.5% proparacaine hydrochloride was instilled in both eyes before taking the measurements. An average of ten readings was taken for each eye.

Assessment of Near Work and Outdoor Activity

All subjects completed a near-work questionnaire developed and validated by Saw et al.[26] Subjects, with the help of their parents, were instructed to fill in the number of hours spent on different types of near work and outdoor activities listed in the questionnaire to the nearest half hour. Information regarding the working distance for near activities was also obtained.

Further information regarding the number of schooldays, holidays, and academic-topic examination sessions was used to calculate the weighted average of near-work activity for the year, which was then converted into average hours of near work per day. Near-work activity was then calculated in terms of diopter-hours by multiplying the average number of hours of near work per day by the reciprocal of the working distance.[27] Total near-work activity was defined as the sum of diopter-hours of all near-work activities per day. This gives an estimation of the near work not only in terms of the time spent on reading, but also in terms of the accommodative effort.

Assessment of outdoor activity was determined from questions that included outdoor sports (e.g., cricket) and leisure activities (e.g., cycling). Participants were asked to fill in the time spent per day on these activities, which then gave a measure of the total outdoor activity per day. Total outdoor activity per day was defined as the sum of outdoor sports and outdoor leisure activity.

Statistical Analysis

Data were analyzed using SPSS Version 14.0. Refractive error was taken as the mean spherical equivalent refraction. A two-way, between-groups multivariate ANOVA was performed, with refractive error and axial length as continuous dependent variables; near work and outdoor activities were taken as categorical independent variables.

Multiple comparisons between groups for main effects and interaction were performed using independent samples t-test and one-way ANOVA, respectively. For comparing the main effect of near-work activity, subjects were divided into two groups, namely “More

Table 1. Comparison of SE Refraction and Axial Length in Children with Varying Levels of Outdoor and Near-Work Activity

Type of Activity	Refractive Error	Axial Length
Outdoor activity groups		
Less outdoor <1 hr (n = 128)	-1.25 ± 2.0 D	23.89 ± 0.98 mm
More outdoor >1 hr (n = 23)	-0.47 ± 1.32 D	23.27 ± 0.99 mm
	p = 0.022	p = 0.01
Near-work activity groups		
Less near work <18 Dh (n = 113)	-0.74 ± 1.88 D	23.70 ± 1.06 mm
More near work >18 Dh (n = 38)	-2.16 ± 1.83 D	24.03 ± 0.86 mm
	p < 0.0001	p = 0.062

Near Work: >18 Dh" and "Less Near Work: ≤18 Dh". For comparing the main effect of time spent outdoors, subjects were divided into two groups, namely "More Outdoor Time: >1 hour" and "Less Outdoor Time: ≤1 hour."

In order to compare the interaction effect of near work and outdoor activities, subjects were divided into four groups based on their near work, using an 18-diopter-hour (Dh)/day cut-off, and their outdoor activity time, using a 1-hour/day cut-off: (i) Less Near work More Outdoor – LNMO (<18 Dh & >1 hour; n = 15); (ii) Less Near work Less Outdoor – LNLO (<18 Dh & <1 hour; n = 98); (iii) More Near work More Outdoor – MNMO (>18 Dh & >1 hour; n = 5); (iv) More Near work Less Outdoor – MNLO (>18 Dh & <1 hour; n = 33).

Binary logistic regression was done to examine the association between myopia and varying levels of outdoor time and near work after adjusting for age, gender, and myopic family history. Myopia status was taken as the categorical dependent variable; the four groups were the categorical independent variables.

Results

The mean magnitude of near work and the time spent outdoors in this cohort were 18.20 ± 15.37 diopter hours and 48.04 ± 41.35 minutes, respectively, per day. There was no correlation between diopter hours of near work and time spent on outdoor activity (r = -0.07, P > 0.05).

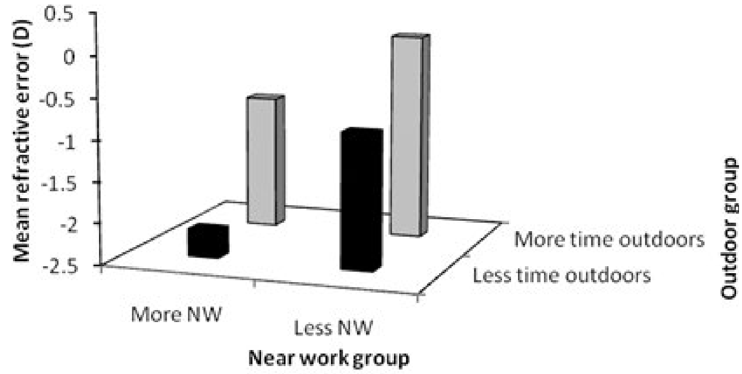

***Figure 1.** Interaction between time spent outdoors and near-work activity for refractive error*

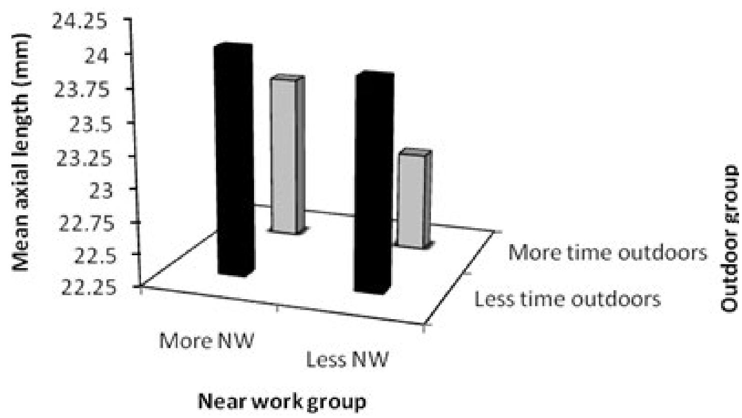

***Figure 2.** Interaction between time spent outdoors and near-work activity for axial length*

Main Effect – Outdoor Time

There was a statistically significant effect of outdoor time on both refractive error (MANOVA $F_{1,149} = 5.07$, $p = 0.026$) and axial length (MANOVA $F_{1,149} = 7.91$, $p = 0.006$). Children who spent less time outdoors had significantly more myopic refractive error and longer axial length than those who spent more time outdoors (Table 1).

Main Effect – Near Work Activity

Near work activity had a significant effect on refractive error (MANOVA $F_{1,149} = 4.88$, $p = 0.029$), but not on axial length (MANOVA $F_{1,149} = 1.74$, $p = 0.19$). Children with more near-work activity had a significantly more myopic refractive error than those with less near work; axial length was not significantly different between the two groups (Table 1).

Table 2. Comparison of SE Refraction and Axial Length in Children with Varying Combinations of Outdoor and Near-Work Activity

Near work * Outdoor groups	Refractive Error	Axial Length
LNLO (n = 98)	-0.97 ± 2.01 D	23.86 ± 0.99 mm
LNMO (n = 15)	0.024 ± 0.94 D	23.02 ± 1.06 mm
P value	0.33	**0.014**
LNLO (n = 98)	-0.97 ± 2.01 D	23.86 ± 0.99 mm
MNLO (n = 33)	-2.17 ± 1.69 D	24.00 ± 0.88 mm
P value	**0.009**	1.00
LNLO (n = 98)	-0.97 ± 2.01 D	23.86 ± 0.99 mm
MNMO (n = 5)	-0.85 ± 1.13 D	23.55 ± 0.81 mm
P value	1.000	1.00
LNMO (n = 15)	0.024 ± 0.94 D	23.02 ± 1.06 mm
MNLO (n = 33)	-2.17 ± 1.69 D	24.00 ± 0.88 mm
P value	**0.001**	**0.01**
LNMO (n = 15)	0.024 ± 0.94 D	23.02 ± 1.06 mm
MNMO (n = 5)	-0.85 ± 1.13 D	23.55 ± 0.81 mm
P value	**0.001**	1.00
MNLO (n = 33)	-2.17 ± 1.69 D	24.00 ± 0.88 mm
MNMO (n = 5)	-0.85 ± 1.13 D	23.55 ± 0.81 mm
P value	**0.001**	1.00

LNMO - Less Near work More Outdoor; LNLO - Less Near work Less Outdoor
MNMO - More Near work More Outdoor; MNLO- More Near work Less Outdoor

Interaction Between Outdoor Time and Near-Work Activity

The interaction between near-work activity and time spent outdoors was significant for both refractive error (MANOVA $F_{1,147} = 6.58$, $p < 0.0001$) and axial length (MANOVA $F_{1,147} = 3.45$, $p = 0.018$) (Figures 1 & 2). Multiple comparisons between the groups are shown in Table 2.

Subjects with more near work and less time spent outdoors were more myopic than those who did less near work and spent more time outdoors (p = 0.001). In the less-outdoor-time groups, subjects with more near work had significantly more myopia than those with less near work (p = 0.009). Among the more-outdoor-time groups, subjects who spent more time on near work had a significantly more myopic SER than those with less near work (p = 0.001). In the more-near-work groups, subjects who spent less time outdoors were more myopic than those with more time spent outdoors (p = 0.001).

Subjects who did more near work and spent less time outdoors had a significantly longer axial length than those with less near work and more time spent outdoors (p = 0.01).

Table 3. Binary Logistic Regression Model for the Likelihood of Myopia after Adjusting for Age, Gender, and Family History of Myopia

Variable	OR (95% CI)	P Value
Age	1.11 (0.90 - 1.37)	0.33
Gender		
Male (n = 69)	Reference category	
Female (n = 82)	0.91 (0.41 - 2.01)	0.82
Family history of myopia (parents/siblings)		
No (n = 106)	Reference category	
Yes (n = 45)	11.59 (3.99 - 33.69)	<0.0001
Time spent outdoors/near work groups		
LNMO (n = 15)	Reference category	
LNLO (n = 98)	3.74 (0.72 – 19.35)	0.12
MNLO (n = 33)	15.23 (2.22 – 104.31)	0.006
MNMO (n = 5)	4.69 (0.35 - 63.62)	0.25

LNMO - Less Near work More Outdoor; LNLO - Less Near work Less Outdoor
MNMO - More Near work More Outdoor; MNLO - More Near work Less Outdoor

In the less-near-work groups, subjects who spent less time outdoors had a significantly longer axial length than those who spent more time outdoors (p = 0.014).

Binary logistic regression model (Table 3) showed that children with a positive family history of myopia were about 11 times more likely to be myopic compared to children who did not have a myopic parent or sibling. Children who did more near work and spent less time outdoors were 15 times more likely to be myopic, compared to children who combined less near work with more outdoor time.

Discussion

Our data shows significantly more myopia in children who spent more time on near work and less time outdoors compared to those with less near work and more outdoor time. These results are consistent with the Sydney Myopia Study,[11] which also showed more myopia in children with high levels of near work and low levels of outdoor activity. Our study results show a similar trend in Indian children. Lin et al.[16] reported a significantly more myopic refractive error in Chinese primary school children with low levels of outdoor activity but did not report the combined effect of near work and outdoor activity.

The reduced odds ratio for myopia in children with less near work and more time spent outdoors suggests a protective association between myopia and outdoor time combined with near-work activity, which remained even after adjusting for myopic family history.

It is possible that higher levels of near-work activity may have prevented children from going outdoors, thereby reducing their daylight exposure, leading to longer axial length and myopia. On the other hand, children who spent more time outdoors showed relatively shorter axial length and lower degrees of myopia, suggesting that the daylight exposure may play a protective role in myopia.[7,8] It is also interesting to note that children who spent more time indoors and had high levels of near work were more myopic than those who spent more time outdoors with similar levels of near activity.

Several mechanisms have been postulated to underlie the relationship between outdoor time and lower levels of myopia. Increased time outdoors could reduce myopia due to the release of dopamine, which is an ocular growth inhibitor, or due to an increased exposure to blue-light chromaticity, resulting in decreased myopia.[28-33] Animal studies have shown that exposure to light intensities above 10,000 lux has a protective effect on myopia.[34-39] Other studies on chicks and guinea pigs have reported that exposure to shorter-wavelength blue light retards eye growth and suppresses myopia.[29-33] As daylight is predominantly blue light, increased outdoor time should result in reduction of myopia. Other mechanisms have also been suggested, including an increase in the depth of focus and reduced image blur due to pupillary constriction in bright light,[11,12] a more uniform pattern of peripheral retinal defocus as a result of less dioptric variation across the retina, and decreased accommodative demand while outdoors.[40]

Although this study has a modest number of patients, with only about 15% of the participants in the more-outdoor groups compared to the less-outdoor groups (Table 3), it still has a good statistical power to show a significant interaction. However, the difference in axial length among children with different levels of near-work activity (Table 2) did not reach statistical significance, although it is approaching significance. A similar number of patients in each group would have been beneficial; however, in a study like this, it is impossible to predict which subjects would fall into which category, as the subjects were recruited consequently. Another possible limitation of the present study is that we used cycloplegic retinoscopy as we had no access to an auto-refractor in the rural clinic. However, when we compared the retinoscopy results to the auto-refractors, there was very good agreement between the two. Hence, we do not believe this would detract from the importance of this study.

Conclusion

In summary, the present study has shown that children with higher near work combined with lower outdoor activity had significantly more myopic refraction and longer axial lengths compared to those who performed lower near work and spent more time outdoors. Increased time spent outdoors combined with less time spent on near work may have a protective role in myopia, independent of myopic family history. These results suggest a need for public health measures and intervention strategies to promote outdoor time among children for myopia prevention and control. Children should be encouraged to spend more time outdoors.

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The authors have no conflicts of interest to declare.

References

1. Holden BA, Jong M, Davis S, et al. Nearly 1 billion myopes at risk of myopia-related sight-threatening conditions by 2050– time to act now. Clin Exp Optom 2015;98:491-4. http://bit.ly/2l8AOMp
2. Holden BA, Fricke TR, Wilson DA, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. Ophthalmol 2016;123:1036-42. http://bit.ly/2mFkQd8
3. Morgan IG, French AN, Ashby RS, et al. The epidemics of myopia: Aetiology and prevention. Prog Retin Eye Res 2018; 62:134-49. http://bit.ly/2laXsnd
4. Zheng YF, Pan CW, Chay J, et al. The economic cost of myopia in adults aged aged over 40 years in Singapore. Invest Ophthalmol Vis Sci 2013;54:7532-7. http://bit.ly/2l90o3S
5. He M, Xiang F, Zeng Y, et al. Effect of time spent outdoors at school on the development of myopia among children in China: A randomized clinical trial. JAMA 2015;314:1142-8. http://bit.ly/2l8KFBK
6. Guggenheim JA, Northstone K, McMahon G, et al. Time outdoors and physical activity as predictors of incident myopia in childhood: A prospective cohort study. Invest Ophthalmol Vis Sci 2012;53:2856-65. http://bit.ly/2kZbyZ6
7. French AN, Ashby RS, Morgan IG, Rose KA. Time outdoors and the prevention of myopia. Exp Eye Res 2013;114:58-68. http://bit.ly/2mHeR7F
8. Sherwin JC, Reacher MH, Keogh RH, et al. The association between time spent outdoors and myopia in children and adolescents: A systematic review and meta analysis. Ophthalmol 2012;119:2141-51. http://bit.ly/2kWzxYR
9. Wu PC, Tsai CL, Wu HL, et al. Outdoor activity during class recess reduces myopia onset and progression in school children. Ophthalmol 2013;120:1080-5. http://bit.ly/2l04FXt
10. Xiong S, Sankaridurg P, Naduvilath T, et al. Time spent in outdoor activities in relation to myopia prevention and control: A meta-analysis and systematic review. Acta Ophthalmol 2017;95:551-66. http://bit.ly/2mB5k1H
11. Rose KA, Morgan IG, Smith W, et al. Myopia, lifestyle, and schooling in students of Chinese ethnicity in Singapore and Sydney. Arch Ophthalmol 2008;126:527-30. http://bit.ly/2lckLNF
12. Rose KA, Morgan IG, Ip J, Kifley A, et al. Outdoor activity reduces the prevalence of myopia in children. Ophthalmol 2008;115:1279-85. http://bit.ly/2mGzr88
13. Dirani M, Tong L, Gazzard G, et al. Outdoor activity and myopia in Singapore teenage children. Br J Ophthalmol 2009;93:997-1000. http://bit.ly/2l9Y0Ke
14. Wu PC, Tsai CL, Hu CH, Yang YH. Effects of outdoor activities on myopia among rural schoolchildren in Taiwan. Ophthalmic Epidemiol 2010;17:338-42. http://bit.ly/2l8HoT7
15. Jones LA, Sinnott LT, Mutti DO, et al. Parental history of myopia, sports and outdoor activities, and future myopia. Invest Ophthalmol Vis Sci 2007;48:3524-32. http://bit.ly/2mGAZ1W
16. Lin Z, Vasudevan B, Jhanji V, et al. Near work, outdoor activity, and their association with refractive error. Optom Vis Sci 2014;91:376-82. http://bit.ly/2lb3DYr
17. Jones-Jordan LA, Sinnott LT, Cotter SA, et al. Time outdoors, visual activity, and myopia progression in juvenile-onset myopes. Invest Ophthalmol Vis Sci 2012;53:7169-75. http://bit.ly/2mzib4v
18. French AN, Morgan IG, Mitchell P, Rose KA. Risk factors for incident myopia in Australian schoolchildren: The Sydney adolescent vascular and eye study. Ophthalmol 2013;120:2100-8. http://bit.ly/2kYXY85
19. Jin JX, Hua WJ, Jiang X, et al. Effect of outdoor activity on myopia onset and progression in school-aged children in Northeast China: the Sujiatun Eye Care Study. BMC Ophthalmol 2015; e pub ahead of print 9 July 2015;15:73. doi: 10.1186/s12886-015-0052-9. http://bit.ly/2mHlfff
20. Wu PC, Chen CT, Lin KK, et al. Myopia prevention and outdoor light intensity in a school-based cluster randomized trial. Ophthalmol 2018;125:1239-50. http://bit.ly/2l0a6Wn
21. Murthy GV, Gupta SK, Ellwein LB, et al. Refractive error in children in an urban population in New Delhi. Invest Ophthalmol Vis Sci 2002;43:623-31. http://bit.ly/2lbl6zY
22. Dandona R, Dandona L, Srinivas M, et al. Refractive error in children in a rural population in India. Invest Ophthalmol Vis Sci 2002;43:615-22. http://bit.ly/2lblRJk
23. Dandona R, Dandona L, Srinivas M, et al. Population-based assessment of refractive error in India: The Andhra Pradesh Eye Disease Study. Clin Exp Ophthalmol 2002;3:84-93. http://bit.ly/2mHmyuz
24. Saxena R, Vashist P, Tandon R, et al. Prevalence of myopia and its risk factors in urban school children in Delhi: The North India Myopia study (NIM study). PLoS ONE 2015; 10: e0117349. doi:10.1371/journal.pone.0117349. http://bit.ly/2lb6ZdZ
25. Saxena R, Vashist P, Tandon R, et al. Incidence and progression of myopia and associated factors in urban school children in Delhi: The North India Myopia study (NIM study). PLoS ONE 2017;12(12):e0189774. http://bit.ly/2mHnsY5
26. Saw SM, Nieto FJ, Katz J, Chew SJ. Distance, lighting, and parental beliefs: Understanding near work in epidemiologic studies of myopia. Optom Vis Sci 1999;76:355-62. http://bit.ly/2mHnzTv
27. Zadnik K, Satariano WA, Mutti DO, Sholtz RI, Adams AJ. The effect of parental history of myopia on children's eye size. JAMA 1994;271:1323-27. http://bit.ly/2kZlf9W
28. Feldkaemper M, Schaeffel F. An updated view on the role of dopamine in myopia. Exp Eye Res 2013;114:106-19. http://bit.ly/2l8yKUD
29. Rucker FJ, Wallman J. Chicks use changes in luminance and chromatic contrast as indicators of the sign of defocus. J Vis 2012;12:1-13. http://bit.ly/2kWJxkR
30. Foulds WS, Barathi VA, Luu CD. Progressive myopia or hyperopia can be induced in chicks and reversed by manipulation of the chromaticity of the ambient light. Invest Ophthalmol Vis Sci 2013;54:8004-12. http://bit.ly/2mFKkqL

31. Long Q, Chen D, Chu R. Illumination with monochromatic long-wavelength light promotes myopic shift and axial elongation in new born pigmented guinea pigs. Cutan Ocul Toxicol 2009;28:176-80. http://bit.ly/2kWKKZr

32. Liu R, Qian YF, He JC, et al. Effects of different monochromatic lights on refractive development and eye growth in guinea pigs. Exp Eye Res 2011;92:447-53. http://bit.ly/2mFy8X4

33. Jiang L, Zhang S, Schaeffel F, et al. Interactions of chromatic and lens-induced defocus during visual control of eye growth in guinea pigs. Vision Res 2014;94:24-32. http://bit.ly/2kZosGw

34. Ashby R, Ohlendorf A, Schaeffel F. The effect of ambient illuminance on the development of deprivation myopia in chicks. Invest Ophthalmol Vis Sci 2009;50:5348-54. http://bit.ly/2lbqEKO

35. Cohen Y, Peleg E, Belkin M, Polat U, Solomon AS. Ambient illuminance, retinal dopamine release and refractive development in chicks. Exp Eye Res 2012;103:33-40. http://bit.ly/2mHsbJd

36. Smith EL, Hung LF, Huang J. Protective effects of high ambient lighting on the development of form deprivation myopia in rhesus monkeys. Invest Ophthalmol Vis Sci 2012;53:421-8. http://bit.ly/2mVfjPJ

37. Smith EL 3rd, Hung LF, Arumugam B, Huang J. Negative lens induced myopia in infant monkeys: Effects of high ambient lighting. Invest Ophthalmol Vis Sci 2013;54:2959-69. http://bit.ly/2lqBGMp

38. Backhouse S, Collins AV, Phillips JR. Influence of periodic vs. continuous daily bright light exposure on development of experimental myopia in the chick Ophthalmic Physiol Opt 2013;33:563-72. http://bit.ly/2mHsbJd

39. Ashby RS, Schaeffel F. The effect of bright light on lens compensation in chicks. Invest Ophthalmol Vis Sci 2010;51:5247-53. http://bit.ly/2leILjm

40. Flitcroft DI. The complex interactions of retinal, optical and environmental factors in myopia etiology. Prog Retin Eye Res 2012;31:622-60. http://bit.ly/2lptTP4

41. Flitcroft DI. The complex interactions of retinal, optical and environmental factors in myopia etiology. Prog Retin Eye Res 2012; 31: 622-60. http://bit.ly/2mWYQe1

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