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Lifestyle and sleep-related behaviours in children with myopia

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Abstract

Background Myopia is a prevalent disease influenced by both genetic and environmental factors. This study aims to explore myopia risk factors, including the association between night-time reading habits under low illumination in children.

Methods A cross-sectional survey was conducted in Argentina as part of the "Myopia Awareness Campaign" in June 2024. A total of 1,298 children aged 7–15 years were included. Data on self-reported myopia, reading habits, illumination levels, type of housing, outdoor time, and parental high myopia were collected through a 23-question Google Forms survey disseminated by ophthalmologists. Multiple logistic regression was used to assess the association between these factors and self-reported myopia.

Results The prevalence of self-reported myopia in children was 23.7%. Significant risk factors for myopia included older age (odds ratio, OR: 1.15; 95% Confidence Intervals, CI:1.08–1.23), high-intensity reading (OR: 1.69; 95% CI:1.12–2.55), parental high myopia (OR: 2.88; 95% CI:2.07-4.00), less outdoor time (OR: 0.98; 95% CI: 0.97–0.999), and living in a house without a garden (OR:1.49; 95% CI:1.12-2.00). While initial unadjusted analysis suggested that reading at night in the dark was associated with myopia, the association lost significance after adjusting for age.

Conclusions This study highlights the importance of environmental factors and lifestyle choices in myopia development. Although reading at night in the dark appeared as a potential risk factor, further research is needed to clarify its role in myopia development and progression. The existence of accessible outdoor areas may increase the time children spent outdoors helping to mitigate myopia incidence.

Keywords Reading at night, Myopia, Illumination, Housing

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Background

Myopia is a prevalent disease that can be prevented by managing lifestyle risk factors. Although, family history of high myopia is a well-known risk factor for early onset myopia [1], environmental factors may play a determinant role in the development of myopia [2]. It is known that outdoor exposure to natural light is an important factor in the prevention of myopia onset and probably in arresting its progression [3]. It is also known that intense reading is associated with myopia [4]. Lag of accommodation during reading may induce ocular growth by temporal integration of hyperopic defocus signals in the perifoveal area [5, 6]. Reading black text in white background is related with OFF contrast stimuli and was shown to decrease choroidal thickness, a finding that aligns with increased ocular growth stimulated by reading [7]. More recently, screen time has been identified as an additional risk factor for myopia [8, 9].

For the past few years research on myopia had been focusing on environmental factors [10], including illumination and spectral composition of light, as stimulation with both blue and red monochromatic lights have showed some promising results in myopia control [11–14]. Illumination in kindergarten years has been shown to affect refractive error in children; 5 year old children had less hyperopic reserve when exposed to low illuminated schools environments [15]. A study in China has shown that increasing illumination from 200 to 500 lx in classrooms decreases myopia progression in children [16]. Cohen et al. found that chicks growing in low light of 50 lx (near the upper limit of mesopic vision) develop myopia in 3 months' time with no spectacle or form deprivation intervention [17].

Going to bed late was also associated with myopia progression in one study [18]. But the study did not explore children's reading habits while going to sleep or their bedroom illumination [18]. Special myopic defocus spectacles for myopia control have recently shown choroidal thickening in young subjects while they were reading with lights on [19], showing promise for future clinical trial of myopia control spectacles in children [20]. However, with lights off, under mesopic conditions, choroidal response was not present [21]. Those results may suggest that reading at night with lights off may prevent the eye to recognize the STOP growth signal, as the retinal circuits which balance ON and OFF contrast are very sensitive to illumination [22, 23].

The present study was conducted in Argentina, a country which has shown a low prevalence of myopia: 15% in a semi-rural environment [24], and near 30% in an university population [25] or in a sample of office-workers with high academic achievement [26]. A previous pilot study explored self-reported myopia prevalence in a clinical population of Buenos Aires city, with a questionnaire on children's habits when going to bed [27]. The study found a prevalence of myopia of 21% in a clinical population. However, the questionnaire did not include questions on other myopia risk factors. Thus, a new questionnaire was developed to include known myopia risk factors recruiting a more representative sample.

This study aims to analyze the association between myopia and children's habits at night when going to bed, especially considering reading with low illumination as a risk factor for myopia.

Materials and methods

This was a cross-sectional study carried out in Argentina during the "Myopia Awareness Campaign" promoted by the Argentinian Council of Ophthalmology in June 2024, to celebrate the anniversary of the famous Argentine writer Jorge Luis Borges. The campaign was developed to increase the awareness about myopia, prevention strategies and myopia control strategies. A Spanish Google form questionnaire with 23 questions was developed and disseminated by email and WhatsApp trough the Argentinian Council of Ophthalmology to more than 5000 registered ophthalmologists in the whole country. Ophthalmologists disseminated the survey link among their networks and outpatients contact list. The link to the survey was also disseminated on radio and television. The questionnaire was tested on a previous pilot study among patients of two ophthalmological centers in Buenos Aires city [27]. The internal consistency was analyzed by asking several consecutive questions about children who did not use spectacles, showing consistent responses concerning the prevalence of non-spectacle use. The results of the previous pilot study showed a myopia prevalence of 21% in children from a clinical population of outpatients, which is similar to previously published population data [24, 26]. Myopia is a well-known disease in Argentina, where 97% of the population is literate.

The target population were parents of school aged children 7 to 15 years old. As we aimed to analyze reading habits in children, only children above seven years old were selected as it is the lower age limit for children to learn how to read in Argentina and most school myopia develops after that age [1]. The questionnaire included an explanation of the anonymity and did not collect other demographic data except age and sex of the children. The Ethics Committee of the Argentine Council of Ophthalmology was consulted and stated that for studies based on population surveys with no intervention and anonymity, ethical approval is waived. All participants who answered the questionnaire gave informed consent to participate in the study.

Data were gathered during six weeks and parents could answer the survey as many times as children they had, once for each child. The questionnaire collected the

following data: whether the child had myopia or not, if the child read before going to bed and how much time the task involved, if there were none, one or two lights on while reading, how many days per week the child reads at night, if the child preferred books or smartphones and the type of house the child lived in (house with garden or high rise building or house without garden). In addition, questions on books and smartphones reading intensity (low and high), outdoor time (hours per week, h/w) and parental history of high myopia were included.

Statistical methods

Data were gathered in an excel table which was automatically provided in the Google forms questionnaire. Text data were converted to code numbers in the excel table. Numeric variables such as age or time outdoors were expressed as means and standard deviation (SD). Discrete variables were expressed as percentages.

We examined the association of predictive factors with self-reported myopia (yes; no) using a multiple logistic regression model. The variable self-reported myopia was derived from the questionnaire answers and those classified as having myopia reported the use of spectacles for myopia. The "no" myopia group included children that reported the use of spectacles but not for myopia (presumable astigmatic or hyperopes) and those who did not use spectacles (presumable emmetropes or low compensated hyperopes). The logistic model included significant variables in the unadjusted logistic regression, such as age, books intensity, smartphones intensity, reading at night, how long was the reading at night, housing type, outdoor time, bed timing and parental high myopia. The fit of the logistic regression model was assessed using the Hosmer-Lemeshow goodness-of-fit test. Odds ratios (OR) and 95% confidence intervals (CI) are reported. $P<0.05$ was considered statistically significant. All statistical analyses were carried with SPSS (IBM, United States, version 28).

Table 1 Descriptive statistics of the main variables

	*n**	Mean (SD) or (%)
Age (y)	1298	10.69±2.53
Sex		
Boys	668	51.5
Girls	630	48.5
Books		
Low intensity	1132	87.2
High intensity	166	12.8
Smartphones		
Low intensity	671	51.7
High intensity	627	48.3
Reading at night		
No	742	57.2
Yes, with 1 or 2 lights on	394	30.4
Yes, in the darkness	162	12.5
How long is the reading at night		
No reading at night	735	56.6
30 min or less	359	27.7
1 h or more	204	15.7
How many days reads at night		
No reading at night	722	55.6
1 or 2 days per week	267	20.6
3 or more days per week	309	23.8
Housing		
With a garden	667	51.4
High rise or without garden	631	48.6
Outdoor time (h/wk)	1298	17.67±8.71
Bed timing		
8 or 9 pm	190	14.6
10 pm or later	1108	85.4
Parental high myopia		
No	957	73.7
Yes	218	16.8
Unknown	123	9.5

y, years; h/wk, hours per week; n, number; SD, Standard deviation

*For individual variables 'n' may not add up to 1298 due to missing data

Results

A total of 1298 children were included in the study, with a mean age of 10.69±2.53 years and 51.5% were males ($n=668$). Forty-eight percent of children attended school full time. The characteristics of the children are shown in Table 1. About half of the children read at night in bed before sleeping (49.5%), with 12.5% reading with lights off (only the light of the device) and 30.4% reading with one or two lights on. The duration of the reading at night was 30 min or less in 27.7% of the children and 1 h or more in 15.7%. The reading at night occurred 1 or 2 days per week in 20.6% of the children and 3 or more days in 23.8%. Smartphones or tablets were used with high intensity at night in 48.3% of cases compared to 12.8% for books. High rise buildings or houses without gardens were the home of 48.6% of subjects, while houses with gardens were the homes of 51.4% of the children. In 56.4% of the cases parents said that their house had high illumination. Houses with gardens were reported to have higher illumination (62.6%) compared to high rise houses (16.8%) or houses without gardens (20.6%; $p<0.001$). Children spent a mean of 17.7±8.7 h per week outdoors.

The self-reported prevalence of myopia was 23.7% and 9.2% reported to have spectacles prescription before age 6. The mother or the father were reported to have high myopia in 16.8% of the cases.

Table 2 shows the characteristics of children stratified by myopia and no myopia. Children with myopia were significantly older, were more likely to read books and use smartphones with higher intensity, read at night in the darkness and for longer periods compared with

Table 2 Comparison of characteristics in children with myopia and without myopia

	Myopia (*n* = 1298)*				
	n	**No**	***n***	**Yes**	***p***
Age (y)	990	10.42 ± 2.49	308	11.58 ± 2.48	< 0.001
Sex					
Boys	518	77.5%	150	22.5%	0.27
Girls	472	74.9%	158	25.1%	
Books					
Low intensity	879	77.7%	253	22.3%	0.002
High intensity	111	66.9%	55	33.1%	
Smartphones					
Low intensity	546	81.4%	125	18.6%	< 0.001
High intensity	444	70.8%	183	29.2%	
Reading at night					
No	580	78.2%	162	21.8%	< 0.001
Yes, with 1 or 2 lights on	307	77.9%	87	22.1%	
Yes, in the darkness	103	63.6%	59	36.4%	
How long is the reading at night					
No reading at night	567	77.1%	168	22.9%	< 0.001
30 min or less	289	80.5%	70	19.5%	
1 h or more	134	65.7%	70	34.3%	
How many days reads at night					
No reading at night	557	77.1%	165	22.9%	0.41
1 or 2 days per week	206	77.2%	61	22.8%	
3 or more days per week	227	73.5%	82	26.5%	
Housing					
With a garden	536	80.4%	131	19.6%	< 0.001
High rise or without garden	454	71.9%	177	28.1%	
Outdoor time (h/wk)	990	18.13 ± 8.61	308	16.22 ± 8.87	0.001
Bed timing					
8 or 9 pm	165	86.8%	25	13.2%	< 0.001
10 pm or later	825	74.5%	283	25.5%	
Parental high myopia					
No	771	80.6%	186	19.4%	< 0.001
Yes	127	58.3%	91	41.7%	

y, years; h/wk, hours per week; n, number; SD, Standard deviation

Mean ± SD for continuous variables and percentages for categorical variables

*For individual variables 'n' may not add up to 1298 due to missing data

P indicates difference in participant characteristics by outcome status

non-myopes. In addition, myopic children were more likely to live in high rise buildings or houses without gardens, engaged in less outdoor time, had a later bedtime and were more likely to have parents with high myopia than non-myopic children. Sex and the number of days the children read at night during the week were not significantly different between myopic and non-myopic children. Figures 1 and 2 illustrate these variables.

Time spent outdoors was significantly ($p < 0.001$) associated with the type of housing; children living in houses with gardens (18.56±8.62 h/w) spent more time outdoors than children living in high rise homes or homes without garden (16.72±8.70 h/w). In addition, among children with myopia, those living in high rise homes or homes without garden tended to spend less time outdoors. Myopic children overall spent less time outdoors than non-myopic children (Figs. 3 and 4).

The results of the logistic regression analysis showed that older age, reading books with higher intensity, parental high myopia, less outdoor time and not having a house with garden were significantly associated with higher odds of myopia (Table 3). Although, reading at night in the darkness was associated with myopia in the unadjusted model, the significance disappeared after adjusting the model for age. Older children were found to read significantly ($p < 0.001$) more in the darkness (12.56±2.42 years) compared with reading with 1 or two lights on (10.40±2.52 years) and not reading at night (10.44±2.40 years).

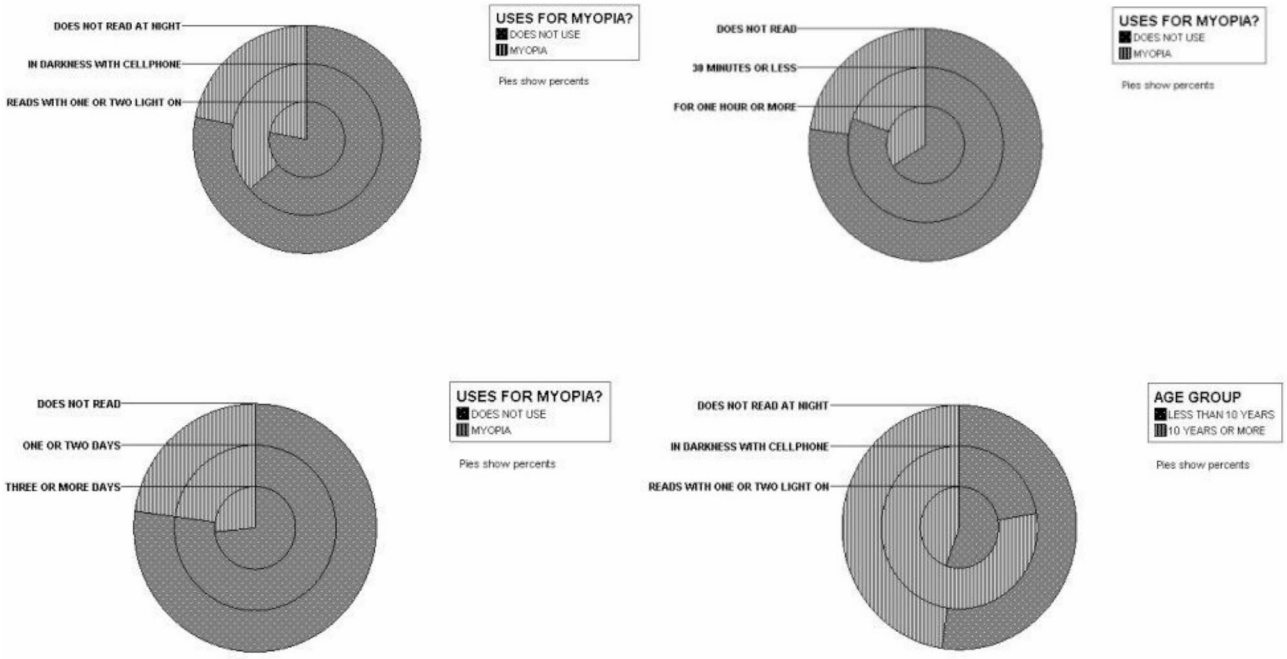

Fig. 1 Clustered pie charts with relevant variables in the univariate analysis split by myopia– no myopia group, or by older– younger age group

Discussion

The present study examined the association between various behavioural, environmental, and parental risks factors for myopia in children. We found that older age, reading books with higher intensity, parental high myopia, less outdoor time and not having a house with garden were significantly associated with myopia. The association between older age, reading books and family history of myopia and increased odds of myopia aligns with existing literature [28].

Availability of green spaces and its relationship with myopia has been previously explored in China [29], where higher incidence of myopia was related to lower green space exposure. Our study found that children who did not have access to a house with a garden were at higher odds of developing myopia. This finding supports the growing body of evidence suggesting that outdoor time plays a protective role against myopia. Children with myopia spent less time outdoors in our study and living in a house without garden was associated with less outdoor time, both in myopic and non-myopic subjects. This further emphasizes the importance of encouraging outdoor time to mitigate the risk of myopia. Interventions aimed at reducing myopia incidence in children should consider promoting outdoor activities, particularly in urban settings where access to natural environments like gardens may be limited.

The questionnaire used in the current study was developed to test whether children read at night in the darkness with smartphones. In a previous pilot study, we developed a questionnaire that only had questions about myopia prevalence and was tested in a small clinical sample ($n = 588$). In the pilot study, we found a prevalence of self-reported myopia of 21%, and 31% of the children reported to read at night with lights off. Thus, we developed the current study to test lifestyle habits, especially reading at night with smart devices.

While reading at night in darkness initially appeared to be associated with myopia in the unadjusted model in the present study, this association lost significance after adjusting for age. This suggests that the observed relationship may be confounded by age, with older children - who are more likely to be myopic - also being more inclined to read in the dark. Indeed, our findings show that older children read significantly more in darkness compared to reading with one or two lights on or not reading at night at all. This habit does not seem to have been explored in previous myopia research. Illumination is crucial on how the retina perceives the balance between ON and OFF contrast [22, 23]. This light adaptation of the retina could affect emmetropization, as it seems that under low illumination in mesopic conditions the retina does not perceive accurately the ON contrast that stops the eye from growing [21]. Interestingly, one study using objective measurements with wrist light sensors found that myopic children were less time in complete darkness during the last hours of the day, suggesting that not being in the dark could be a risk for myopia [30]. However, myopic children in that study spent more time than the emmetropic peers under mesopic conditions

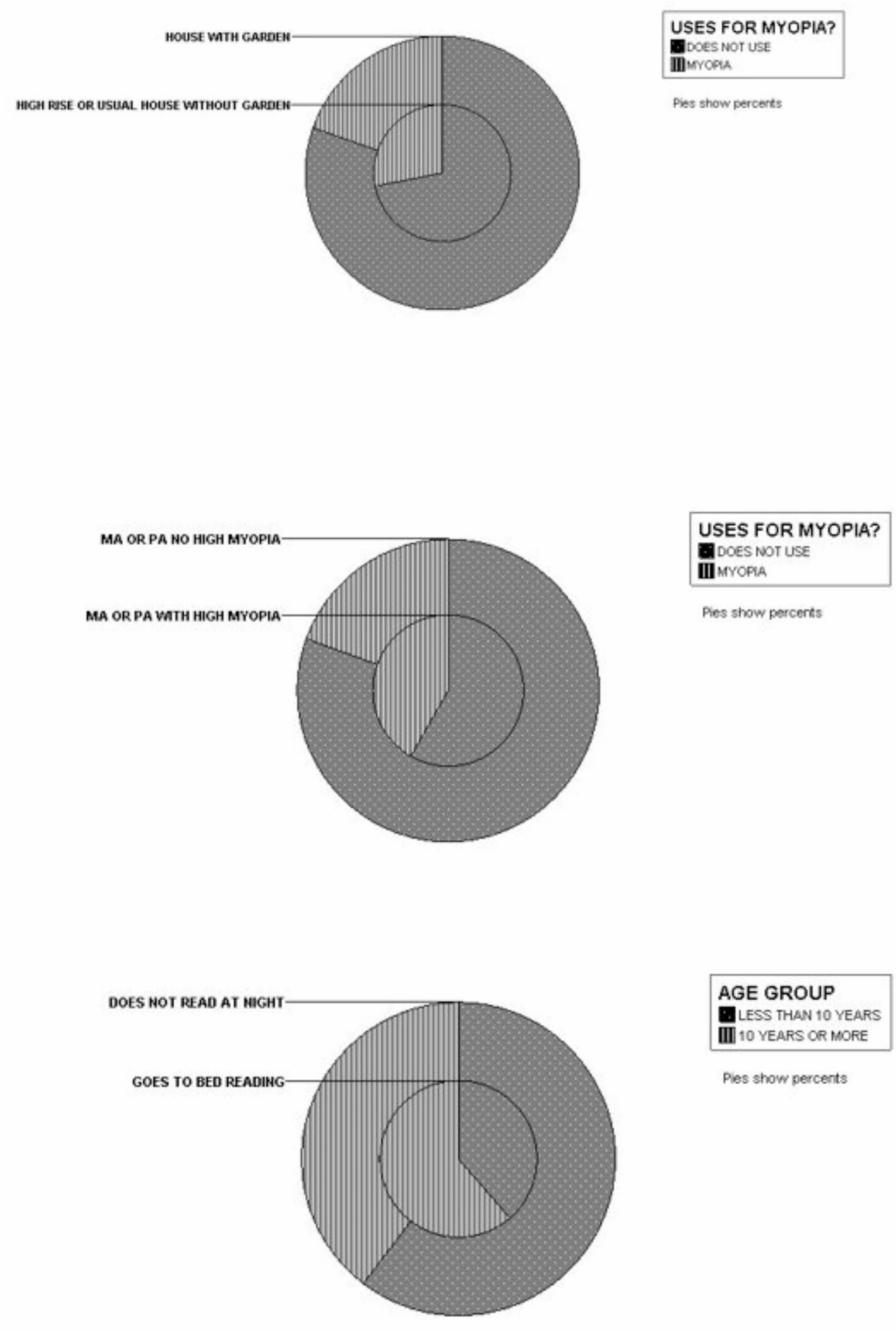

Fig. 2 Clustered pie charts other variables in the univariate analysis, like reading at night, parental myopia and housing. (PA & MA: mother and father with high myopia)

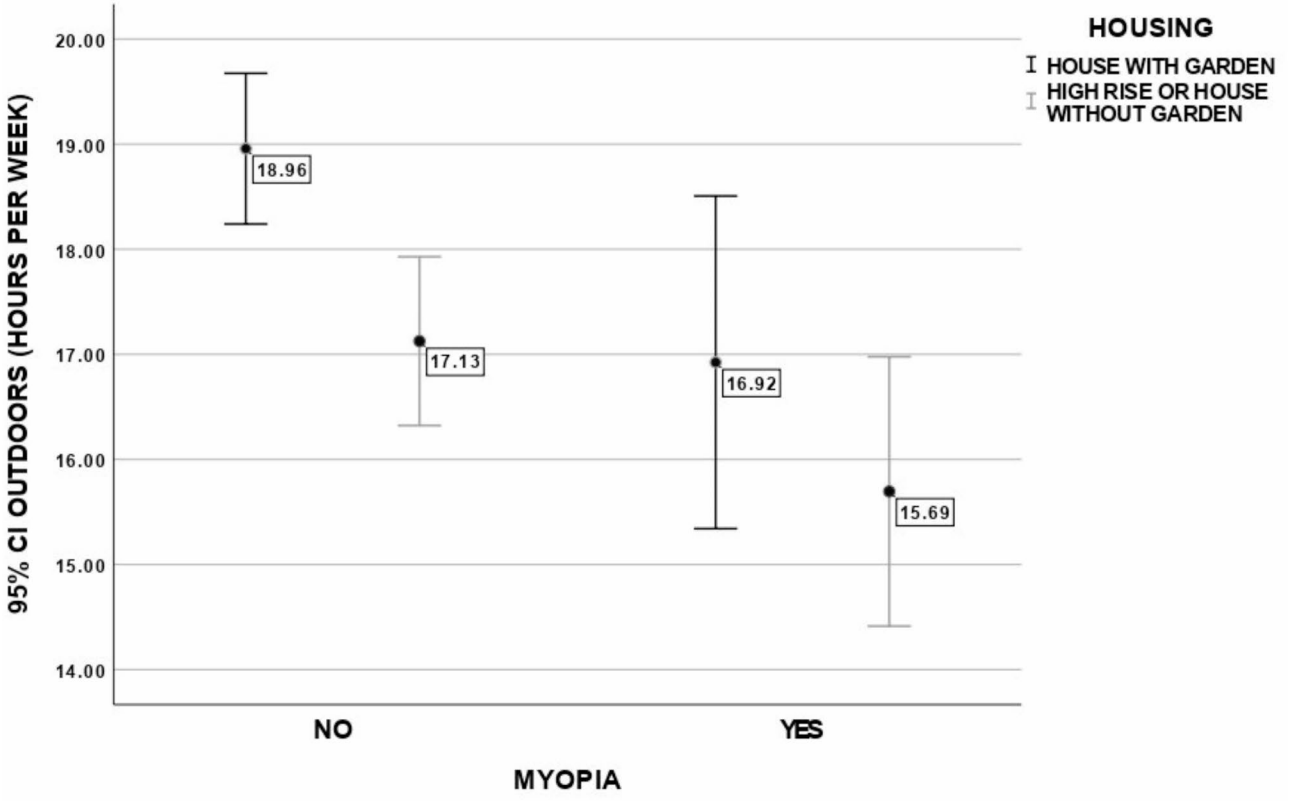

Fig. 3 Time spent outdoors stratified by house with garden and high rise or house without garden and by myopia. Error bars show the 95% confidence intervals (CI) of mean

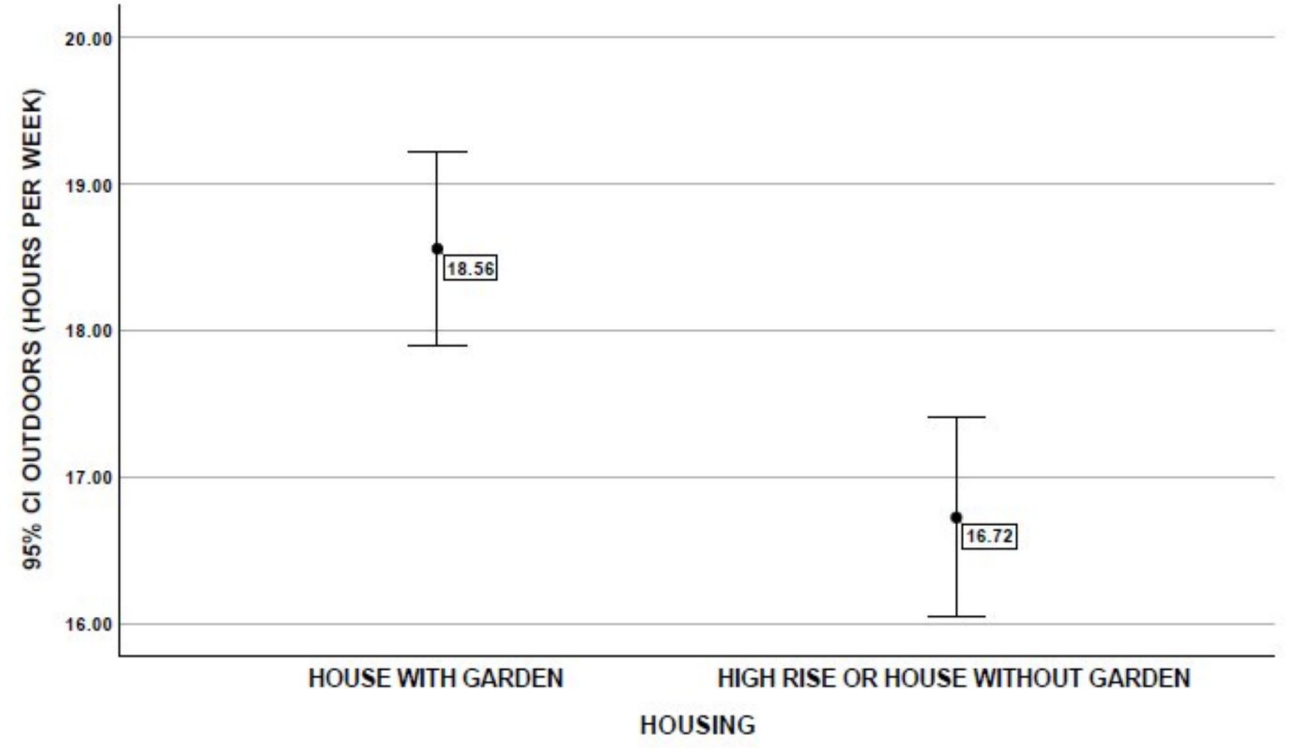

Fig. 4 Time spent outdoors stratified by type of housing. Error bars show the 95% CI of mean

Table 3 Association of key risk factors with myopia

Variables	Myopia			
	Unadjusted β (95% CI)	*p*	Multivariable OR (95% CI)	*p*
Age (y)	1.20 (1.14–1.27)	< 0.001	1.15 (1.08–1.23)	< 0.001
Books				
Low intensity	Reference	0.003	Reference	0.013
High intensity	1.72 (1.21–2.45)		1.69 (1.12–2.55)	
Smartphones				
Low intensity	Reference	< 0.001	Reference	0.17
High intensity	1.80 (1.39–2.34)		1.25 (0.91–1.70)	
Reading at night				
No	Reference		Reference	
Yes, with 1 or 2 lights on	1.02 (0.76–1.36)	0.92	1.00 (0.59–1.67)	0.99
Yes, in the darkness	2.05 (1.43–2.95)	< 0.001	1.41 (0.81–2.46)	0.22
How long is the reading at night				
No reading at night	Reference		Reference	
30 min or less	0.82 (0.60–1.12)	0.21	0.86 (0.52–1.45)	0.58
1 h or more	1.76 (1.26–2.47)	< 0.001	1.11 (0.64–1.92)	0.72
Housing				
With a garden	Reference	< 0.001	Reference	0.007
High rise or without garden	1.60 (1.23–2.07)		1.49 (1.12-2.00)	
Outdoor time (h/wk)	0.97 (0.96–0.99)	< 0.001	0.98 (0.97–0.999)	0.029
Bed timing				
8 or 9 pm	Reference	< 0.001	Reference	0.28
10 pm or later	2.26 (1.46–3.52)		1.31 (0.80–2.16)	
Parental high myopia				
No	Reference	< 0.001	Reference	< 0.001
Yes	2.97 (2.17–4.06)		2.88 (2.07-4.00)	

CI, Confidence intervals; OR, Odds ratio

The model included age, books, smartphones, reading at night, how long is the reading at night, housing, outdoor time, bed timing and parental high myopia

[30], perhaps showing that myopic children might have gone to bed reading while emmetropic children turned-off their lights waiting until they got asleep. A recent study showed an increasing trend in these habits [31].

It has been shown that bright light prevents experimental myopia progression when applied in the last hours of the day but not in the morning or at midday, and that myopic defocus is most effective in the afternoon than in the morning [32, 33]. It is probable that what children do in the last two hours before sleep could be related to myopia onset and progression. That is probably because the retino choroidal signal for ocular growth may be present during the whole day, but as the eye grows more during the night, the signal sent in the last hours of the day may be more important for ocular growth than that from the morning. However, further research is necessary to confirm this hypothesis.

There are several limitations of this study. The cross-sectional design limits the ability to infer causality. Additionally, questionnaires are subject to recall-bias. To test the consistency of responses, the same question was asked more than one time in different ways. Analysis of the answers showed consistent responses and similar results for each of the similar questions. For example, in four questions there was an option for "my child does not read at night" and the proportion of children in those questions ranged from 57.2 to 55.6%. There were four questions related with self-reported myopia, ("my son does not use spectacles for myopia") and the answers ranged between 76.3% and 71.9%, showing good consistency in the responses about spectacle use. The questionnaire defined "parental high myopia" as six diopters in the spectacles or contact lenses of the parents. It also had an option where the subject could answer "I don't understand what high myopia is". This last option was taken by 123/1298 subjects (9.4% of the sample) showing that most parents had previous knowledge on high myopia.

This study recruited a convenience sample that is not necessarily population based. It can be considered an unselected sample with data of schoolchildren from a network of parents related to the ophthalmic community, perhaps with over-representation of high myopic parents, as can be seen in results section. Nevertheless, the slight differences in sex distribution with more males at school years coincides with the 50.8% prevalence of males in the 7–14 years in the general population of Argentina according to the last census [34]. In addition, myopia was self-reported by the parents of school aged

children. Although, the Argentine population is knowledgeable with the word myopia, there may be subjects that reported inaccurately the refractive error of their children. We assumed that children not using spectacles at all were not myopic because Argentina is well known for the refractive error screening campaigns in schools which provide spectacles for every child. The rates of self-reported myopia prevalence in this study are similar to the prevalence reported in previous populations studies done in the country [24–26].

Conclusions

In addition to parental high myopia, lifestyle and environmental factors play a fundamental role in the development of myopia. Older age, intense reading habits, and environmental conditions, such as living in a house without a garden and limited outdoor exposure are key contributors to myopia. This study found that many children go to bed reading at night in mesopic conditions under low illumination. This habit could be a non-explored risk factor for myopia, although the association with myopia become non-significant after adjustment of age. Thus, prospective studies using refractive error measurements with cycloplegic refraction, including the possible risk factor of reading at night with low illumination, are necessary to further clarify if this is a new risk factor for myopia.

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Author contributions
Each author has made substantial contributions to the conception, OR design of the work; OR the acquisition, analysis, OR interpretation of data; OR the creation of new software used in the work; OR have drafted the work or substantively revised itAND to have approved the submitted version (and any substantially modified version that involves the author's contribution to the study); AND to have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Data availability
Data and materials in this study will be shared in an excel dataset at a reasonable request by emailing last author (Rafael Iribarren at rafairibarren@gmail.com).

Declarations

Ethics approval and consent to participate
The questionnaire included an explanation of the anonymity and did not collect other demographic data except age and sex of the children. The **Ethics Committee of the Argentine Council of Ophthalmology** was consulted for this study, and the authorities stated that for studies based on population surveys with no intervention and anonymity, the ethical approval was waived. All participants who answered the questionnaire gave informed consent to participate in the study.

Consent for publication
N/A.

Competing interests
Leonardo Fernández Irigaray and Rafael Iribarren report personal fees from NOVAR outside the submitted work. Virginia Zanutigh is president of the Argentinian Council of Ophthalmology. Carla Lanca reports personal fees from Eyerising International outside the submitted work. Andrzej Grzybowski: Grants outside the submitted work from Alcon, Bausch&Lomb, Zeiss, Teleon, J&J, CooperVision, Hoya, Essilor, Thea, Polpharma, Viatris, and Lectures for Thea, Polpharma, Viatris, Eyerising, Essilor, Alcon; Member of Advisory Boards: Nevakar, GoCheckKids and Thea.

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