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Prevalence of Myopia in America: A Systematic Review and Meta-Analysis*

Prevalencia de miopía en América: revisión sistemática y metaanálisis

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ABSTRACT

In recent years, prevalence of myopia in the world has increased significantly. The aim of this research work is to consider the combined prevalence of myopia in America, according to the following categories: age, race, gender, and region. Such research will be done also in harmony with the reports found in scientific literature. A systematic review of the literature found in the following databases was carried out: medline, embase, and lilacs. The aim was searching cross-sectional studies containing myopia prevalence information. To find the combined prevalence, the double arc sine method of fixed or random effects by Freeman-Tukey was used. 15 research studies that included 45,349 individuals from the United States, Brazil, and Paraguay, were identified in the literature; studies of subjects aged 0-96 years old. The prevalence of myopia varied from 1.2% to 48% with differences between male and female of 18,4% [95% CI: 13.9-22.8] and 19.8% [95% CI: 18.9-20.7], respectively. The global prevalence of myopia in rural areas was 1.4% [95% CI: 1.3-1.5], and in urban areas 14.3% [95% CI: 13.3-15.2]. At the same time, some differences were identified based on race. In the case of the white race 15.4% [95% CI: 14.4-16.3], Afrodescendants 20.6% [95% CI: 19.6-21.5] and other races (Spanish, non-Spanish, and African American) 2.9% [95% CI: 1.97-3.82]. The lowest figures of myopia prevalence were identified in rural areas in pre-school children (14.1%). There is, probably, a relationship in use and exposure time to electronic items such as screens, in contrast with the development of other indoor activities as outdoor exposure as an environmental factor to slow myopia.

Keywords: myopia, prevalence, America, meta-analysis, review.

* Review article.

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RESUMEN

En los últimos años, la prevalencia de la miopía en el mundo ha aumentado significativamente. El objetivo de este trabajo fue identificar la prevalencia combinada de la miopía en América según las siguientes categorías: edad, raza, género y región. Se realizó una revisión sistemática de la literatura en las bases de datos Medline, Embase y Lilacs, con el objetivo de buscar estudios transversales con información sobre la prevalencia de miopía. Para encontrar la prevalencia combinada se utilizó el método de doble arco sinusoidal de efectos fijos o aleatorios de Freeman-Tukey. Se analizaron 15 estudios que incluyeron a 45.349 personas de Estados Unidos, Brasil y Paraguay, de 0 a 96 años. El rango de prevalencia varió del 1,2 % al 48 % con diferencias entre hombres y mujeres del 18,4 % [IC del 95 %: 13,9-22,8] y el 19,8 % [IC del 95 %: 18,9-20,7], respectivamente. La prevalencia global en las zonas rurales fue del 1,4 % [IC del 95 %: 1,3-1,5] y en las zonas urbanas del 14,3 % [IC del 95 %: 13,3-15,2]. Al mismo tiempo, se identificaron algunas diferencias basadas en la raza. En el caso de la raza blanca 15,4 % [IC 95 %: 14,4-16,3], raza negra 20,6 % [IC 95 %: 19,6-21,5] y otras razas (española, no española y afroamericana) 2,9 % [95 % CI: 1,97-3,82]. Las cifras más bajas de prevalencia de miopía se identificaron en áreas rurales en niños en edad preescolar. Es probable que exista una relación en el uso y el tiempo de exposición a elementos electrónicos como pantallas en contraste con el desarrollo de otras actividades en interiores.

Palabras clave: miopía, prevalencia, América, metaanálisis, revisión.

INTRODUCTION

Nearly 22.9% of the world's population suffers from myopia, and 2.7% from severe myopia >5D (1). According to estimates in 2050 prevalence will reach a 49.8%, which represents an increase of 911 million people suffering from this refractive error (2, 3). In America, current prevalence is estimated in 23%, and the projections for North America are 42.1%, Central America 34.2%, and South America 32.4% (1).

By 2016, in urban populations, estimates show a 48% prevalence for America (2), but, in contrast, other ethnic groups particularly Caucasian have significant higher rates (3). Studies in the region show a prevalence of 21.9%, 17.9%, respectively between this group and Afrodescendants (4). On the other hand, some reports show important variations in categories of gender and age, being women the most affected population with prevalence of up to 6% compared to men (4). Respecting age, evidence shows that people between 20 and 30 have a higher incidence of refractive error (72%) (5). These results might be the consequence of long term expositions to electronic devices and short distance view activities, probably due to high academic activities (6). At the same time, there is an increase in prevalence of myopia in people with comorbidities such as glaucoma or cataracts, especially adults older than 40 years (2, 4). Despite the above mentioned, up to this present date, there is not consolidated data available respecting the scope of such variations in America, which makes it difficult to establish preventive strategic activities or preventive activities. On the other hand, keeping into account the region's diverse social and geographic heterogeneity, a comprehensive assessment of the present conditions of these populations is required. The purpose of this research was to compare the prevalence of myopia in America through a systematic review of available literature and a meta-analysis.

METHODS

A systematic review of available literature was carried out searching for national prevalence cross-sectional studies that were conducted at different levels —national, regional and local— in the American continent, which main focus was the assessment of myopia prevalence.

Search strategy

An exhaustive search of literature was conducted from 1990 to 2020 in three medical literature databases: Medline, Embase and Lilacs, and the following search strategies were applied for Medline and Embase ((((“Epidemiology”[Mesh]) OR (“Prevalence”[Mesh] OR “Cross-Sectional Studies”[Mesh])) OR (“Surveys and Questionnaires”[Mesh] OR “Health Surveys”[Mesh])) AND (((“Refractive Errors”[Mesh]) OR ((myopia*) OR near-sightedness))) NOT Asia*) NOT (“surgery”). In Lilacs database, the search term was “mesh myopia”. In both cases, the search was limited to three languages: English, Portuguese, and Spanish, and to humans. The research studies that were considered were those published according to the described indexation excepting search in grey literature.

Selection of literature

Two researchers carried out, on an independent basis, the initial review of article titles and abstracts. In this stage, the contents of each article were verified in connection with the presentation of a probable estimation of myopia prevalence in America. Disagreements respecting final inclusion were settled by consensus. Duplicate articles were discarded, as well as those not showing prevalence of myopia figures directly, nor those not including risks or rates information. Prospective, retrospective, or experimental studies, as well as estimations in institutionalized populations were not included in this research. Studies without a definite population group, geographical location, age range, or classification of myopia were excluded.

Quality of assessments and data extraction

For quality assessment, the inspection list for observational studies (AHRQ) was used (7). The items considered included aspects as population definition, eligibility, terms used to identify individuals, population origin, evaluators blinding, test verification, analysis of variables confusion, description and analysis of excluded individuals, description of data collection, conducted tests, and percentage of incomplete data.

All the literature with an evaluation score greater or equal to 7 were included in the review (7). For information extraction, an electronic sheet was built and fed including information concerning the author, year of publication, country, age, ethnic group, the employed refraction method, and the definition of myopia and prevalence.

Data analysis

Studies heterogeneity was assessed by using the formula $\chi 2$ (8). Global prevalence was combined using the double arc sine method by Freeman-Tukey through a fixed effect model if the P value of the test $\chi 2$ was lower than 0.05. If that condition was not met, the employed method was one of random effect (9). Subgroup analyses were carried out according to age, race, gender, and region. The findings are exposed in charts of meta-analysis along with their graphical representation. All these procedures were completed in the statistical application STATA, 14th Version.

RESULTS

Article search in Medline, Embase and Lilacs databases yielded a positive result of 12.489 publications up to the year 2018, and 182 articles out of that number were potentially eligible. According to eligibility criteria, 163 articles were excluded, and 3 articles did not meet quality evaluation (AHRQ). Finally, 15 articles were included in this work (Figure 1). Samples included in this review varied in size: from 476 to 6024 participants and ages from 0 to 96 years.

The rating method of myopia was through spherical equivalent (SE), calculated as sphere + half of minus cylinder. SE ≤-0.50D was identified in 10 studies and SE ≤-1.00D in 5 studies; all of them employed the autorefraction method, and 9 of them used Cyclopentolate at 1% (Table 1).

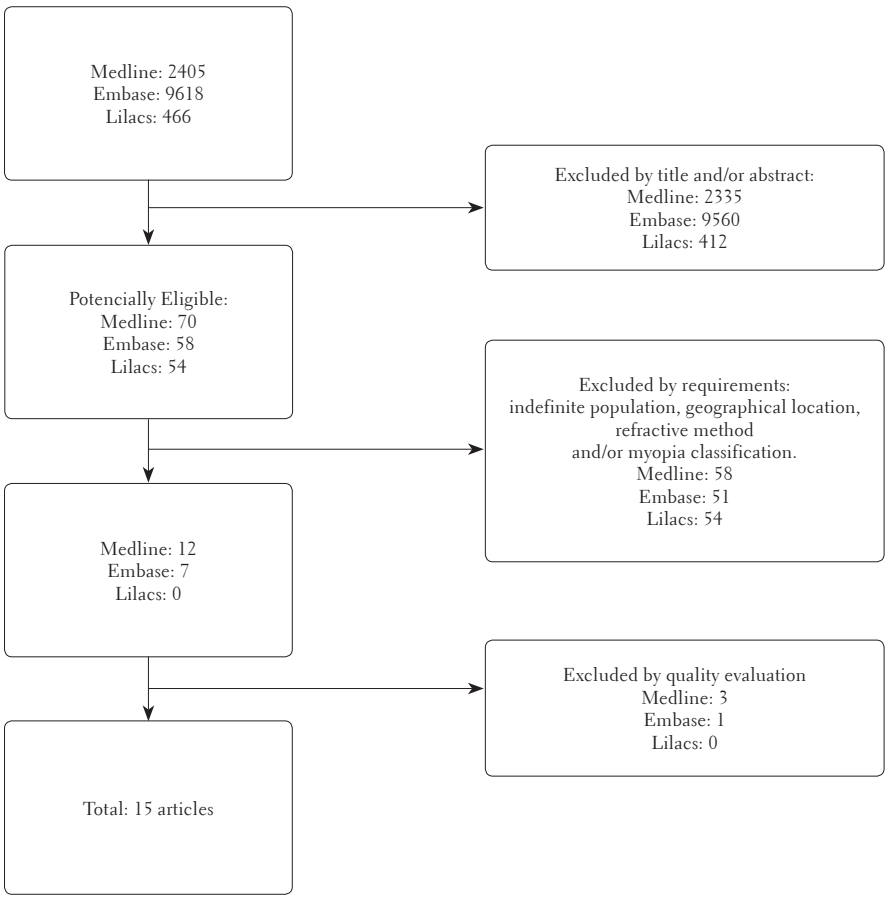


FIGURE 1. **Flowchart for articles review**

Source: own work

TABLE 1. **Characteristics of included studies**

AUTHOR (YEAR)	COUNTRY/REGION	AGE	POPULATION	REFRACTION METHOD	MYOPIA DEFINITION	QUALITY EVALUATION
Giordano L. et al. (2009)[12]	USA/ Urban population in LA, California	6-71 months	3990	Autorefractometry with cycloplegia	SE ≤-1.00D	8
Gen Wen et al. (2010)[13]	USA / Urban population in LA, California	6-72 months	6024	Autorefractometry with cycloplegia	SE ≤1.00 D	9
Ge Wen et al. (2013)[14]	USA / Urban population	6-72 months	3008	Autorefractometry with cycloplegia	SE ≤1.00D	9
Hendler et al. (2016)[15]	USA / Urban population in LA	3-5 years	1007	Autorefractometry with cycloplegia	SE ≤0.50D	8
Moraes Ibrahim et al. (2013)[16]	Brazil / Urban population, Gurupi, Tocatins	10-15 years	1590	Autorefractometry with cycloplegia	SE ≤0.50D	8
Lira R.P. et al. (2014)[17]	Brazil / Urban population, Campinas	5-18 years	1100	Autorefractometry with cycloplegia	SE ≤ 0.50D	8
Lira R.P. et al. (2017)[18]	Brazil / Urban population, Campinas	6-17 years	778	Autorefractometry with cycloplegia	SE ≤0.50D	7
Carter M. et al. (2013)[19]	Paraguay / Rural population	5-16 years	476	Autorefractometry with cycloplegia	SE ≤0.50D	7
Signes-Soler I. (2017)[20]	Paraguay / Rural population	3-20 years	1466	Autorefractometry with cycloplegia	SE ≤0.50D	7
Joanne Katz J. et al. (1997)[21]	USA / Urban population, Baltimore	40+ years	5028	Autorefractometry without cycloplegia	SE ≤ 0.50D	9

Author (Year)	Country/Region	Age	Population	Refraction method	Myopia definition	Quality evaluation
Suh-Yub Wu et al. (1999)[6]	USA / Urban population, Barbados	40+ years	4330	Autorefractometry without cycloplegia	SE ≤ 0.50D	10
Tarczy–Hornoch et al. (2006)[22]	USA / Urban population, California	40+ years	5396	Autorefractometry without cycloplegia	SE ≤1.00D	10
Rasanamar K. Sandhu et al. (2013)[4]	USA /Urban population, Arizona	40+ years	4272	Autorefractometry without cycloplegia	RE ≤0.50D	10
Chen-Wei Pan (2013)[23]	USA	45+ years	4430	Autorefractometry without cycloplegia	SE ≤1.00 D	9
Schellini S.A. et al. (2009)[24]	Brazil	30-39 years	2454	Autorefractometry without cycloplegia	SE ≤0.50D	8

Source: own work

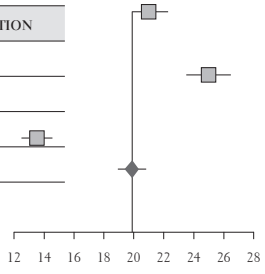
In North America, 9 research studies were identified (USA), in South America, a number of 7 articles (Brazil, Paraguay and Colombia) were identified. Due to quality standards of the present study, studies from Central America were not included.

Respecting myopia prevalence on a global scale for America, it was estimated a 15.9%. The figures for North America (USA) were between 0.7% (2) and 48% (10); while in South America (Paraguay, Brazil), they oscillated between 1.4% (11) and 29.7% (12). There were some differences between men and women in myopia prevalence of nearly 2% (18.4% and 19.8%) (Figure 2).

In connection with the reported differences, both in urban and rural areas, there were 2 important research studies, one from Paraguay that reported prevalence of myopia in urban areas as 1.4% [95% CI: 1.3-1.5], while in 8 research studies from the United States and Brazil, the prevalence of myopia in rural areas was 14.3% [95% CI: 13.3-15.2] (Figure 3). The prevalence of myopia in people younger than 20 years of age was 8.9% [95% CI: 8.0-9.8, while in people older than 20 years of age, it was 26.9% [95% CI: 25.9-27.8] (Figure 4). Myopia prevalence in white race was identified in a combined value of 15.4% [95% CI: 14.4-16.3]; black people, 20.6% [95% CI: 19.6-21.5], and other races (Hispanic, non-Hispanic) with 2.9% [95% CI: 1.97-3.82] (Figure 5).

Prevalence of myopia in women

Study	Event	Population	Prevalence	Standard deviation
Joanne J, 1997	1060	5028	21.0	0.006
Suh-Yub Wu, 1999	1082	4330	24.9	0.007
Tarczy-Hornoch, 2006	733	5396	13.5	0.005
Global			19.8	0.004



Prevalence of myopia in men

Study	Event	Population	Prevalence	Standard deviation
Joanne J, 1997	1086	5028	21.5	0.006
Suh-Yub Wu, 1999	844	4330	19.4	0.006
Tarczy-Hornoch, 2006	766	5396	14.1	0.005
Global			18.4	0.004

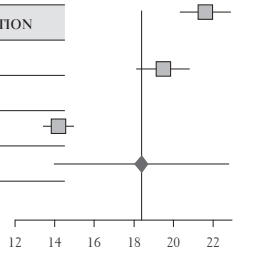
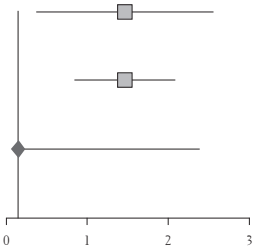


FIGURE 2. **Prevalence of myopia in women and men**

Source: own work

Prevalence of myopia in rural areas

Study	Event	Population	Prevalence	Standard deviation
Cartes M, 2013	7	476	1.4	0.005
Signes-Soler, 2017	22	1466	1.5	0.003
Global			1.4	0.004



Prevalence of myopia in urban areas

Study	Event	Population	Prevalence	Standard deviation
Giordano L, 2009	123	3990	3.0	0.002
Wen G, 2010	307	6024	5.0	0.002
Ge Wen, 2013	75	3008	2.4	0.002
Hendler, 2016	211	1007	20.9	0.144
Moraes I, 2013	49	1590	3.0	0.004
Lira RP, 2014	121	1100	11.0	0.010
Lira RP, 2017	74	778	9.5	0.011
Joanne Katz J, 1997	1070	5028	21.2	0.006
Suh-Yub Wu, 1999	948	4330	21.8	0.007
Tarczy-Hornoch, 2006	906	5396	16.7	0.005
Global			14.3	0.004

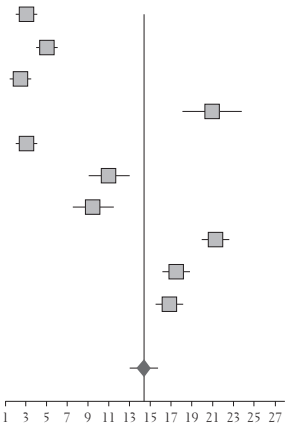
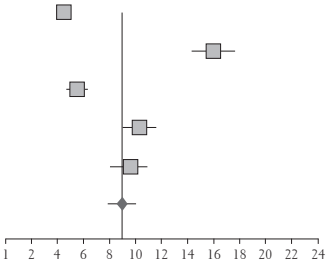


FIGURE 3. **Prevalence of myopia in rural and urban areas respectively**

Source: own work

Prevalence of myopia in people younger than 20 years of age

Study	Event	Population	Prevalence	Standard deviation
Wen G, 2010	72	6024	1.1	0.001
Hendler, 2016	211	1007	20.9	0.014
Moraes I, 2013	49	1590	3.0	0.004
Lira RP, 2014	121	1100	11.0	0.010
Lira RP, 2017	74	778	9.5	0.011
Global			8.9	0.004



Prevalence of myopia in people older than 20 years of age

Study	Event	Population	Prevalence	Standard deviation
Joanne Katz J, 1997	1086	5028	21.5	0.006
Suh-Yub Wu, 1999	900	4330	20.7	0.006
Tarczy-Hornoch, 2006	906	5396	16.7	0.005
Rasanamar K, 2013	2050	4272	47.9	0.010
Chen-Wei Pan, 2013	1111	4430	25.0	0.007
Shellini SA, 2009	728	2454	29.6	0.010
Global			26.9	0.004

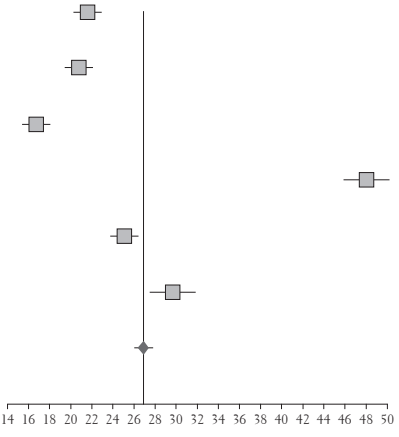
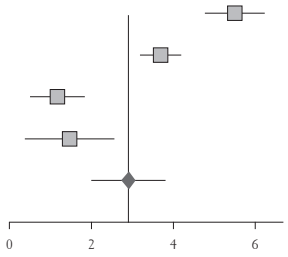


FIGURE 4. **Prevalence of myopia in people younger and older than 20 years of age respectively**

Source: own work

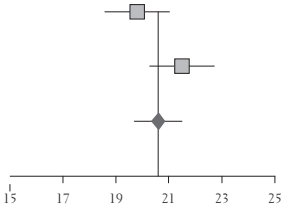
Prevalence of myopia in white people

Study	Event	Population	Prevalence	Standard deviation
Giordano L, 2009	219	3990	5.4	0.003
Ge Wen, 2010	226	6024	3.7	0.002
Ge Wen, 2013	12	1007	1.1	0.003
Carter M, 2013	7	476	1.4	0.005
Global			2.9	0.004



Prevalence of myopia in black people

Study	Event	Population	Prevalence	Standard deviation
Joanne Katz J, 1997	995	50028	19.7	0.006
Suh-Yub Wu, 1999	1160	5396	21.4	0.006
Global			20.6	0.004



Prevalence of myopia in other races

Study	Event	Population	Prevalence	Standard deviation
Giordano L, 2009	123	3990	3.0	0.002
Joanne Katz J, 1997	1070	5028	21.2	0.006
Suh-Yub Wu, 1999	948	4330	21.8	0.007
Global			15.4	0.004

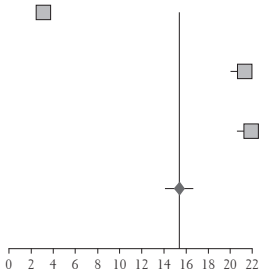


FIGURE 5. **Prevalence of myopia in white people, black people and other races, respectively**

Source: own work

DISCUSSION

Given the fact that myopia implies irreversible anatomic changes that are the consequence of refractive error progression, a number of research studies from around the world have reported its prevalence, particularly in Asia, where the reported figures are higher (3). Findings in America on the same topic show values around 16%. In contrast, the lowest prevalence on myopia was found in children from the United States younger than 5 years old (1.2%) (13). This finding might be the result of a physiological emetropization process during the initial years of life which works as an anatomic factor for the appearance of myopiain children (14, 15). At the same time, global prevalence of myopia in children younger than 12 years of age was 8.9%. These figures are similar to those showed in the Hashemi research (6.09%), in which farsightedness was the most prevalent refractive error in America (16).

Galvis et al. (2018), in 10 districts of Colombia (Miopur study) identified a prevalence of 12.9% being slightly greater in adolescents of 15 years (14.7%). In our results, the prevalence of myopia in urban regions was greater, reaching 15.7% (17). In adult populations the results of tests are potentially affected by the simultaneity of other diagnoses such as glaucoma or cataracts. For instance, in patients older than 80 years of age, myopia prevalence raised up to 55.1% due to the presence of nuclear cataracts in 42%, glaucoma in 11%, and ocular hypertension in 13% of the participants (4). In contrast, according to the findings in Rasanamar studies (2), in the Latin American population older than 40 years of age, where participants suffering from any ocular illness were

excluded, myopia prevalence was 48% (2), which reinforces, on one side, the concept of the degenerative nature of the illness in parallel with aging processes (18). Also, on the other hand, the study highlights the importance of prevention and care promotion to counteract, as much as possible, the effects of high myopia (19). In addition, previous reports have pointed out to other factors of environmental nature (20)controlled trial [RCT], as well as social, financial and/or cultural kind (21), that may cause an impact in the occurrence of this illness. Respecting this research, the results of this work agree with the previous evidence, showing higher rates of prevalence of myopia in urban areas in comparison to rural areas (22). Such higher difference is related to higher schooling levels in which population is involved, implying more near looking activities, and in general the use of electronic devices for longer periods of time during the day (23) thus limiting outdoor activities (24).

Regarding race, there are differences in prevalences. For instance, in our results, black race reported the highest prevalence of this refractive error with a 20.6%, which harmonizes with the meta-analysis of global prevalence in childhood of 19.9% (3). Nevertheless, on a global scale, the highest prevalence of myopia has been found in Asian population (90%) (3). This variation has been linked to a combination of genetic and environmental factors (25).

In the scope of this review, something that must be highlighted is the heterogeneity of this report, and the classification of refractive errors, where SE is considered from ≤0.50D up to ≤1.00D as classification parameters. The measurement of these refractive errors might underestimate or overestimate prevalence figures (3). In addition, the diagnosis method was not standardized in all cases, only in some studies cyclopentolate at 1% was used for diagnosis confirmation, regardless of current evidence that prescribes the application of the topical in populations under 50 years of age, which might be useful as a reference in order to determine refractive conditions (26, 27).

Considering the geographical population of the included research studies, and in view of the reported differences, it was only kept into account urban and rural disaggregation in USA and Brazil, and rural in Paraguay. At the same time, in Chile, and Mexico, research works were carried out only in main cities; nonetheless, these were excluded in the process of quality evaluation. There is a big difficulty in recognising the problem in terms of homogenization, which leads to prevent visibility in the priority of public agendas, and therefore to a proper attention at a global scale.

CONCLUSION

In conclusion, this research study has identified the highest prevalence in US adults from urban regions. This identification based on race, region and age might awaken the need of proper action plans for populations at high risk of being affected by this health problem.

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REFERENCES

1. Holden B, Fricke TR, Wilson D, Jong M. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. Ophthalmology. 2016;123(5): 1036–1042.
2. Hopf S, Pfeiffer N. Epidemiologie der Myopie. Ophthalmologe. 2016; 114(1): 20-23.
3. McFadden SA. Understanding and Treating Myopia: What More We Need to Know and Future Research Priorities (International Myopia Conference Proceedings Paper). Optom Vis Sci. 2016;93(9): 1061-1063. Available from: https://doi.org/10.1097/OPX.0000000000000932
4. Sandhu RK, Munoz BE, Swenor BK, West KS. Refractive error and visual function difficulty in a

Latino population. Ophthalmology. 2012;119(9):1731-1736. Available from: https://doi.org/10.1016/j.ophtha.2012.03.003

5. Rudnicka AR, Kapetanakis VV, Wathern AK, Logan NS, Gilmartin B, Whincup PH et al. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for aetiology and early prevention. Br J Ophthalmol. 2016;100(7): 882–890. Available from: https://doi.org/10.1136/bjophthalmol-2015-307724
6. Wu SY, Nemesure B, Leske MC. Refractive errors in a black adult population: The Barbados Eye Study. Invest Ophthalmol Vis Sci. 1999;40(10): 2179–2184.
7. Hrynchak PK, Mittelstaedt A, Machan CM, Bunn C, Irving E. Increase in myopia prevalence in clinic-based populations across a century. Optom Vis Sci. 2013;90(11): 1331–1341. Available from: https://doi.org/10.1097/OPX.0000000000000069
8. Huang H-M, Chang DS-T, Wu P-C. The Association between Near Work Activities and Myopia in Children-A Systematic Review and Meta-Analysis. PloSone. 2015;10(10): e0140419. Available from: https://doi.org/10.1371/journal.pone.0140419
9. Zeng X, Zhang Y, Kwong JS, Zhang C, Li S, Sun F, Niu Y, Du L. The methodological quality assessment tools for preclinical and clinical studies, systematic review and meta-analysis, and clinical practice guideline: a systematic review. J Evid Based Med. 2015;8(1): 2–10. Available from: https://doi.org/10.1111/jebm.12141
10. Ades AE, Lu G, Higgins JP. The interpretation of random-effects meta-analysis in decision models. Med Decis Making. 2005;25(6): 646–654. Available from: https://doi.org/10.1177/0272989X05282643
11. Li X, Wang J, Zhou J, Huang P, Li J. The association between post-traumatic stress disorder and shorter telomere length: a systematic review and meta-analysis. J Affect Disord. 2017;15(218): 322–326. Available from: https://doi.org/10.1016/j.jad.2017.03.048
12. Giordano L, Friedman DS, Repka MX, Katz J, Ibironke J, Hawes P, Tielsch J. Prevalence of Refractive Error among Preschool Children in an Urban Population: The Baltimore Pediatric Eye Disease Study. Ophthalmology. 2009;116(4): 739–746. Available from: https://doi.org/10.1016/j.ophtha.2008.12.030
13. Multi-Ethnic Pediatric Eye Disease Study Group. Prevalence of myopia and hyperopia in 6 to 72 months old African American and Hispanic Children: The Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology. 2010; 117(1): 140-147.e3. Available from: https://doi.org/10.1016/j.ophtha.2009.06.009
14. Wen G, Tarczy-Hornochl K, McKean-Cowdin R, Cotter S, Borchert M, Lin J et al. Prevalence of Myopia, Hyperopia and Astigmatism in NonHispanic White and Asian Children: Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology. 2013;120(10): 2109–2116. Available from: https://doi.org/10.1016/j.ophtha.2013.06.039
15. Hendler K, Mehravaran S, Lu X, Brown SI, Mondino BJ, Coleman AL. Refractive Errors and Amblyopia in the UCLA Preschool Vision Program; First Year Results. Am J Ophthalmol. 2016;172: 80-86. Available from: https://doi.org/10.1016/j.ajo.2016.09.010
16. Moraes Ibrahim F, Moraes Ibrahim M, Pomepo de Camargo JR, Veronese Rodrigues ML, Scott IU, Silva Paula J. Visual impairment and myopia in Brazilian children: a population-based study. Optom Vis Sci. 2013;90(3):223–227. Available from: https://doi.org/10.1097/OPX.0b013e31828197fd
17. Lira RP, Santo IF, Astur GL, Maziero D, Passos THM, Arieta CEL. Refractive error in school children in Campinas, Brazil. Arq Bras Oftalmol. 2014;77(3): 203–204. Available from: https://doi.org/10.5935/0004-2749.20140052
18. Lira RPC, Arieta CE, Passos TH, Maziero D, Astur GLV, Espírito Santo ÍF et al. Distribution of Ocular Component Measures and Refraction in Brazilian School Children. Ophthalmic Epidemiol. 2017;24(1): 29-35. Available from: https://doi.org/10.1080/09286586.2016.1254249
19. Carter MJ, Lansingh VC, Schacht G, Río del Amo M, Scalamogna M, France TD. Visual acuity and refraction by age for children of three different ethnic groups in Paraguay. Arq Bras Oftalmol. 2013;76(2): 94–97. Available from: https://doi.org/10.1590/s0004-27492013000200008
20. Signes-Soler I, Hernández-Verdejo JL, Estrella Lumeras MA, Verduras ET, Piñero DP. Refractive error study in young subjects: results from a rural area in Paraguay. Int J Ophthalmol. 2017;10(3): 467–472. Available from: https://doi.org/10.18240/ijo.2017.03.22
21. Katz J, Tielsch JM, Sommer A. Prevalence and Risk Factors for Refractive Errors in an Adult Inner City Population. Investig Ophthalmol Vis Sci. 1997;38(2): 334–340.
22. Tarczy-Hornoch K, Ying-Lai M, Varma R, Los Angeles Latino Eye Study. Myopic refractive error in adult Latinos: The Los Angeles Latino Eye Study. Investig Ophthalmol Vis Sci. 2006;47(5): 1845–1852. Available from: https://doi.org/10.1167/iovs.05-1153
23. Pan CW, Klein BE, Cotch MF, Shrager S, Klein R, Folsom A. Racial variations in the prevalence of refractive errors in the United States: the multi-ethnic study of atherosclerosis. Am J Ophthalmol. 2013;155(6): 1129–1138. Available from: https://doi.org/10.1016/j.ajo.2013.01.009
24. Schellini SA, Durkin SR, Hoyama E, Hirai F, Cordeiro R, Casson RJ. Prevalence of refractive errors in a Brazilian population: the Botucatu eye study. Ophthalmic Epidemiol. 2009;16(2): 90–97. Available from: https://doi.org/10.1080/09286580902737524

25. Medina A. Prevention of myopia by partial correction of hyperopia: a twins study. Int Ophthalmol. 2018;38(2): 577–583. Available from: https://doi.org/10.1007/s10792-017-0493-7
26. Flitcroft DI. Emmetropisation and the aetiology of refractive errors. Eye (Lond). 2014;28(2): 169–179. Available from: https://doi.org/10.1038/eye.2013.276
27. Hashemi H, Fotouhi A, Yekta A, Pakzad R, Ostadimoghaddam H, Khabazkhoob M. Global and regional estimates of prevalence of refractive errors: Systematic review and meta-analysis. J Curr Ophthalmol. 2017 27;30(1): 3-22. Available from: https://doi.org/10.1016/j.joco.2017.08.009