HHS Public Access

Author manuscript

Asia Pac J Ophthalmol (Phila). Author manuscript; available in PMC 2022 February 04.

Published in final edited form as:

Asia Pac J Ophthalmol (Phila). ; 11(1): 52–58. doi:10.1097/APO.0000000000000483.

Vision Screening, Vision Disorders, and Impacts of Hyperopia in Young Children: Outcomes of the Vision In Preschoolers (VIP) and Vision in Preschoolers – Hyperopia In Preschoolers (VIP-HIP) studies

Marjean Taylor Kulp, OD, MS,
The Ohio State University College of Optometry, Columbus, Ohio

Elise Ciner, OD,
Pennsylvania College of Optometry at Salus University, Elkins Park, Pennsylvania

Gui-shuang Ying, PhD,
University of Pennsylvania, Philadelphia, Pennsylvania

T. Rowan Candy, PhD,
Indiana University School of Optometry, Bloomington, Indiana

Bruce D. Moore, OD,
New England College of Optometry, Boston, Massachusetts

Deborah Orel-Bixler, PhD, OD,
University of California, Berkeley School of Optometry, Berkeley, California

VIP Study Group, **VIP-HIP Study Group**

Abstract

This review summarizes clinically relevant outcomes from the Vision in Preschoolers (VIP) and VIP-Hyperopia in Preschoolers (VIP-HIP) studies. In VIP, refraction tests (retinoscopy, Retinomax, SureSight) and Lea Symbols Visual Acuity performed best in identifying children with vision disorders. For lay screeners, Lea Symbols single, crowded visual acuity (VA) testing (VIP, 5-foot) was significantly better than linear, crowded testing (10-foot). Children unable to perform the tests (<2%) were more likely to have vision disorders than children who passed and should be referred for vision evaluation. Among racial/ethnic groups, the prevalence of amblyopia and strabismus was similar while that of hyperopia, astigmatism, and anisometropia varied. Presence of strabismus and significant refractive errors were risk factors for unilateral amblyopia, while bilateral astigmatism and bilateral hyperopia were risk factors for bilateral amblyopia. A greater risk of astigmatism was associated with Hispanic, African American, and Asian race, and myopic and hyperopic refractive error. Presence and severity of hyperopia was associated with higher rates of amblyopia, strabismus, and other associated refractive error. In the VIP-HIP study, compared to emmetropes, meaningful deficits in early literacy were observed in uncorrected

Corresponding author: Marjean Taylor Kulp, OD, MS, The Ohio State University College of Optometry, 338 West 10th Avenue, Columbus, Ohio 43210, kulp.6@osu.edu; phone: 614-688-3336.

Conflict of Interest: None

hyperopic 4- and 5-year-olds (≥+4.0 D or ≥+3.0 D to ≤+6.0 D) associated with reduced near visual function (near VA 20/40 or worse; stereoacuity worse than 240”). Hyperopia with reduced near visual function also was associated with attention deficits. Compared to emmetropic children, VA (distance, near), accommodative accuracy, and stereoacuity were significantly reduced in moderate hyperopes, with the greatest risk in those with higher hyperopia. Increasing hyperopia was associated with decreasing visual function.

Keywords

Vision screening; hyperopia; vision disorders; literacy; attention

Significant refractive error, amblyopia, and strabismus, are the most prevalent preschool vision disorders.[1–9] Findings from the National Eye Institute (NEI)–funded multicenter, multidisciplinary Vision in Preschoolers (VIP) Study conducted in 2 phases from 2001 to 2004 on over 4000 children in the US have provided evidence-based guidelines for preschool vision screening and provided information regarding the prevalence, associated risk factors, and impact of preschool vision disorders.[3,10–36] The NEI-funded, multicenter, multidisciplinary Vision in Preschoolers–Hyperopia in Preschoolers (VIP-HIP) Study (2011 to 2014) (N = 492) subsequently showed the impact of uncorrected, moderate hyperopia on early literacy, attention, and visual function.[37–40] This review provides a summary of 1) pertinent findings from the VIP Study regarding the performance of various vision screening tests and the prevalence and associated risk factors of preschool vision disorders and 2) findings from the VIP-HIP Study regarding the impact of uncorrected hyperopia on early literacy, attention, and visual function.

Selected Outcomes From the VIP Study

Evidence-based Guidelines for Preschool Vision Screening From the VIP Study

In the first phase of VIP,[10] 11 preschool vision screening tests were administered by licensed eyecare professionals to 2588 three- to five-year-old Head Start preschoolers in a mobile unit designed for the study at 5 locations across the US.[41] Screening tests included noncycloplegic retinoscopy, Retinomax Autorefractor (Retinomax), SureSight Vision Screener (SureSight), Lea Symbols Visual Acuity (crowded, linear optotypes at 10 feet), HOTV Visual Acuity (crowded, linear optotypes at 10 feet), Power Refractor II, iScreen Photoscreener, MTI Photoscreener, cover-uncover test (unilateral cover test), Random Dot E stereoacuity, and Stereo Smile II random dot stereoacuity [currently Pediatric Assessment of Stereopsis with a Smile (PASS)]. For autorefractors and photoscreeners, testing was performed up to 3 times (as needed) to meet the manufacturers’ recommended guidelines (eg, for confidence number). To increase testability, a response card was used for VA testing to permit children to identify the letter (H, O, T, V) or symbol (apple, house, circle, square) seen by either naming or pointing. Details of these procedures have been published previously.[10] After screening, children were given a comprehensive vision examination by an optometrist or ophthalmologist (licensed eyecare professional) who was masked to the results of the vision screenings.[10] The comprehensive vision examination included monocular visual acuity [Amblyopia Treatment Study (ATS) protocol], random dot

stereoacuity, cover testing (distance and near), cycloplegic retinoscopy, and an ocular health evaluation with ophthalmoscopy performed according to study protocols. Monocular visual acuities were tested without correction and retested with full cycloplegic correction when visual acuity was below age norm and significant refractive error was present.

The VIP study group compared sensitivity at 1) 90% specificity (meaning, 10% over-referrals, a level expected to be suitable for mass screening) and 2) 94% specificity (because 2 of the tests used a central scoring center and set failure criteria and had a specificity of 94%).[10] Failure criteria were selected for each test to maximize sensitivity for identifying children with any vision disorder at the set specificity (with the exception of tests that used a central reading center for test interpretation). Age-related criteria were determined for visual acuity and stereoacuity tests. Sensitivities of these 11 vision screening tests for identification of vision disorders [amblyopia, strabismus, significant refractive error (hyperopia > 3.25 diopters [D]; myopia > 2 D; astigmatism > 1.5 D; and/or anisometropia > 1 D hyperopia, > 1.5 D astigmatism, or > 3 D myopia), or unexplained reduced visual acuity] were compared at the set specificities (90% and 94%). [10,25] Sensitivities for identification of the most severe vision disorders were also compared [amblyopia, constant strabismus, or severe refractive error (hyperopia ≥ 5 D, myopia ≥ 6 D, astigmatism ≥ 2.5 D)]. Sensitivity is calculated as the percentage of children with a vision disorder who are identified as having the disorder by a screening test (referred), while specificity is the percentage of children without the vision disorder who are identified as not having the disorder (passed). For instance, if the sensitivity was 75%, the screening identified (accurately referred) 75/100 of children with the disorder but did not identify (missed) 25/100 of children who had the disorder. If the specificity of a screening test was 85%, the test accurately passed 85/100 of the children who did not have the vision disorder but over-referred 15/100 of the children with normal vision. Changes in sensitivity and specificity generally occur if referral criteria are changed. Furthermore, sensitivity often decreases when specificity increases and vice versa. Thus, test comparisons should be performed at a set specificity. In other words, once the acceptable percentage of over-referrals has been decided and the corresponding failure criteria determined for each test, the percentages of children with the disorder who were accurately identified for these criteria can be compared across tests.

The VIP study found that tests yielding measures of refractive error in the form of sphere, cylinder, and axis (noncycloplegic retinoscopy and the Retinomax and SureSight Autorefractors) and crowded Lea Symbols Visual Acuity performed best in identifying children with 1) any vision disorder, 2) amblyopia, and 3) the most severe vision disorders.[10,25] These tests of refraction (noncycloplegic retinoscopy and the Retinomax and SureSight autorefractors) performed significantly better in identifying children with 1 or more vision disorders than the photoscreeners (iScreen and MTI) that used their own referral criteria for the presence of vision disorders without providing results in sphere, cylinder, and axis format. Additional analysis showed that as the magnitude of hyperopia (on cycloplegic refraction) increased over the range of 4 D to 10 D, the sphere power measurement of the Power Refractor did not increase correspondingly, suggesting the potential for photoscreeners to fail to identify significant hyperopia.[32,42] Lea Symbols visual acuity testing at 10-feet viewing distance had somewhat higher sensitivity than HOTV visual acuity testing for identification of 1 or more vision disorders, but the differences

were not statistically significant.[19] Referral criteria have been published previously for noncycloplegic retinoscopy, Retinomax and SureSight autorefractors, Lea and HOTV visual acuity tests, Power Refractor II, and Random Dot E and Stereo Smile II stereoacuity (tests that did not use a central reading center for test interpretation).[10,16,25] Children were classified as not passing a test if the failure criteria was met for either eye.[10] Over 99% of children were testable on the tests of refraction (noncycloplegic retinoscopy, Retinomax, SureSight) and visual acuity (crowded Lea Symbols and HOTV).[10] At 90% specificity, the best tests identified about two-thirds of children with 1 or more vision disorders and almost 90% of children with the most severe vision disorders.[10]

In the second phase of the VIP study, 3 of the 4 best tests identified from the first phase of the study that could be administered by trained nurses and lay screeners (who often perform screenings) were used to screen 3- to 5-year-old Head Start children (N = 1452) (Retinomax Autorefractor, SureSight Vision Screener, and crowded Lea Symbols Visual Acuity). The testing by nurse and lay screeners was performed inside the schools in order to provide a real world setting which is often variable from location to location in terms of room size, location, and lighting.[11] Lay screeners performed a single, crowded Lea Symbols visual acuity screening test at 5 feet (Good-Lite Co, Elgin, IL US) which had been developed due to poor performance when lay screeners used the crowded Lea Symbols visual acuity test at 10 feet during initial testing. The VIP single, crowded Lea Symbols visual acuity screening test at 5 feet was designed to facilitate engaging the child in the test (closer test distance and the use of a test wheel which presents a single optotype with crowding bars in a window one at a time) and to facilitate ease of testing and scoring (lower difficulty of single vs linear optotype presentation and the use of a scoring template).[11] Because the Stereo Smile II test of stereoacuity was effective in identifying strabismus, it was also included in Phase II for potential use in combination with refraction screening tests since refractive errors do not always accompany strabismus. A detailed description of these procedures has been published previously.[11] After screening, children were given a comprehensive vision examination by an optometrist or ophthalmologist (licensed eyecare professional) who was masked to the results of the vision screening.[11] The comprehensive vision examination included monocular visual acuity (ATS protocol), stereoacuity, cover testing (distance and near), cycloplegic retinoscopy, and an ocular health evaluation with ophthalmoscopy performed according to study protocols.[11] Testability for each screening test remained high (≥98%) when performed by trained nurse and lay screeners.[11] Median testing times were 2 minutes for autorefraction (both eyes), 4 minutes for monocular visual acuities (both eyes), and 3 minutes for stereoacuity testing.[11] At 90% specificity, similar sensitivities for identification of 1 or more vision disorders were attained with the tests of autorefraction (Retinomax, SureSight) and the VIP single, crowded Lea Symbols visual acuity screening test at 5 feet. The relevant referral criteria have been published previously.[11,16] Receiver operator characteristic (ROC) curve analyses to study the ability of the tests of refraction (noncycloplegic retinoscopy) and autorefraction (Retinomax, SureSight) to detect each type of significant refractive error (myopia, hyperopia, astigmatism, and anisometropia) showed that each of these tests had very high ability to identify children with any type of significant refractive error.[30]

The VIP study in Phase II also showed that referring the children who were unable to complete the screening test had little impact on sensitivity or specificity because ≥98% of children were able to perform each test.[17] However, preschoolers who were unable to perform the best tests of refraction or visual acuity (Retinomax, SureSight, or Lea Symbols visual acuity test) were more than twice as likely to have vision disorders than children who passed the tests. Therefore, children who are unable to complete these vision screening tests should be referred for comprehensive vision examination by an eyecare provider.[17]

Combining Stereo Smile II testing with one of the tests of autorefraction or visual acuity did not improve sensitivities for identifying children with any vision disorder,[11] but did improve sensitivities for identifying children with strabismus (6% to 21%),[21] although the differences were not always statistically significant. Furthermore, children with vision disorders had significantly worse median stereoacuity than children without vision disorders (120 vs 60 seconds of arc, $P < 0.001$). In addition, median stereoacuity was worse in children with the most severe vision disorders compared to children with less severe vision disorders (480 vs 120 seconds of arc, $P < 0.001$).[27]

Prevalence of Vision Disorders and Risk Factors for Amblyopia and Astigmatism Among Head Start Preschoolers in the VIP Study (Secondary Analyses)

Prevalence rates of refractive error, amblyopia, and strabismus in each racial/ethnic group were compared among the 4040 3- to 5-year-old Head Start preschoolers enrolled in the VIP study at 5 clinical sites across the US (Boston, MA; Philadelphia, PA; Columbus, OH; Tahlequah, OK; Berkeley, CA).[3] Sampling weights were used to determine prevalence rates, confidence intervals, and statistical analyses. Participating children were African American (N = 2072), American Indian (N = 343, 323 from Oklahoma), Asian (N = 145), Hispanic (N = 796), and non-Hispanic white (N = 481). Overall, 21.4% of children had 1 or more vision disorders with a similar prevalence across groups ($P = 0.40$) which ranged from 17.9% (American Indian) to 23.3% (Hispanic). The prevalence of amblyopia and strabismus were also similar among groups ($P \geq 0.07$ for both). The prevalence of amblyopia ranged from 3.0% (Asian) to 5.4% (non-Hispanic white), and the prevalence of strabismus ranged from 1.0% (Asian) to 4.6% (non-Hispanic white). Prevalence of hyperopia, anisometropia, and astigmatism did vary ($P \leq 0.01$ for all comparisons) (Table 1). Prevalence of hyperopia >3.25 D ranged from 5.5% (Asian) to 11.9% (non-Hispanic white). Prevalence of anisometropia ranged from 2.7% (Asian) to 7.1% (Hispanic). Prevalence of astigmatism >1.50 D ranged from 4.3% (American Indian) to 11.1% (Hispanic). Myopia >2.00 D was relatively uncommon (<2.0%) in all groups, ranging from 0.2% (American Indian) to 1.9% (Asian).[3]

Strabismus and increased magnitude of refractive error were independently associated with a greater risk of unilateral amblyopia (optically corrected interocular difference in visual acuity of 2 lines or more) ($P < 0.0001$ for each). Greater magnitude of astigmatism and bilateral hyperopia were independently associated with greater risk of bilateral vision reduction that is frequently described as bilateral amblyopia (optically corrected visual acuity in both eyes worse than 20/50 for 3-year-olds or worse than 20/40 for 4- to 5-year-olds) ($P < 0.0001$ for both).[33] Presence and amount of anisometropia (spherical equivalent

>0.5 D, cylindrical anisometropia >0.25 D) also significantly increased the risk of unilateral amblyopia.[24] Greater magnitudes of anisometropia were related to higher rates of unilateral amblyopia, larger interocular differences in visual acuity, and poorer stereoacuity (trend $P < 0.001$).[24]

Risk of astigmatism of 1.5 D or more was associated with race and ethnicity; African American [odds ratio (OR), 1.65; 95% confidence interval (CI), 1.22 to 2.24], Hispanic (OR, 2.25; 95% CI, 1.62 to 3.12), and Asian (OR, 1.76; 95% CI, 1.06 to 2.93) children were more likely to have astigmatism than non-Hispanic white children. American Indian children were less likely to have astigmatism than Hispanic, African American, and Asian children ($P < 0.0001$). Given the prior report of a high prevalence of astigmatism among American Indian preschoolers in several tribes in Arizona,[43] the risk of astigmatism may vary among tribes of American Indians. In the VIP Study, astigmatism was associated more with myopia (OR, 4.50; 95% CI, 3.00 to 6.76) and hyperopia (OR, 1.55; 95% CI, 1.29 to 1.86) than nonsignificant refractive error.[28] These data largely support reports from population-based studies of pediatric eye conditions in the US[7–9,44,45] and Singapore.[46,47]

Associations Between Hyperopia and Other Visual Findings in Head Start Preschoolers in the VIP Study (Secondary Analysis)

In another secondary analysis of VIP data, associations between presence and severity of hyperopia (as determined by most positive meridian on cycloplegic retinoscopy) and presence of amblyopia, strabismus, and other types of refractive error were investigated.[31] Children with high hyperopia (≥+5.00 D, N = 163) and moderate to high hyperopia (>+3.25 D, N = 472) had significantly higher rates of amblyopia (51.5% for ≥+5.00 D; 34.5% for >3.25 D) than children with refractive error ≤+3.25 D (2.8%) (OR, 36.5; 95% CI, 25.3 to 52.6 for ≥+5.00 D; OR, 18.1; 95% CI, 13.8 to 23.8 for >+3.25 D, $P < 0.0001$ for both). Children with high hyperopia (≥+5.00 D) or moderate to high hyperopia (>+3.25 D) also had significantly higher rates of strabismus (32.9% for ≥+5.00 D; 17.0% for >3.25 D) than children with refractive error ≤+3.25 D (2.2%) (OR, 21.9; 95% CI, 14.7 to 32.7 for ≥+5.00 D; OR, 9.1; 95% CI, 6.6 to 12.7 for >3.25 D, $P < 0.0001$ for both). The presence of moderate to high hyperopia (>+3.25 D) was also associated with a higher rate of anisometropia (26.9% vs 5.1%; OR, 6.8; 95% CI, 5.3 to 8.8; $P < 0.0001$) and astigmatism (29.4% vs 10.3%; OR, 3.7; 95% CI, 2.9 to 4.6; $P < 0.0001$). Among nonstrabismic, nonamblyopic children, median stereoacuity of children with refractive error ≤+3.25 D (60”) was better than that of hyperopic children (N = 206) (120”) ($P < 0.0001$); children with moderate hyperopia (>+3.25 D to <+5.00 D) had better median stereoacuity (120”) than those with high hyperopia (≥+5.00 D) (480”) ($P < 0.0001$).[31]

Selected Outcomes From the VIP-HIP Study

Associations Between Hyperopia and Early Literacy and Attention in the VIP-HIP Study

The VIP-HIP Study determined the associations between uncorrected, moderate hyperopia and early literacy and attention among 4- and 5-year-old preschoolers and kindergarteners with hyperopia or emmetropia (N = 492).[37] Associations with near visual function were also determined. Children with amblyopia, strabismus, or a history of prior refractive error

correction were excluded. Eligible children had uncorrected hyperopia (≥3.0 D to ≤6.0 D in the most hyperopic meridian of 1 or both eyes, astigmatism ≤1.5 D, anisometropia ≤1.0 D) or emmetropia (hyperopia ≤1.0 D; astigmatism, anisometropia, and myopia <1.0 D) based on cycloplegic refraction. Measures of visual function were monocular distance visual acuity (crowded HOTV) and binocular near visual acuity (crowded HOTV; Precision Vision, Woodstock, IL, USA), accommodative accuracy (how closely the child was focused to the near visual target) (Monocular Estimation Method; Grand Seiko autorefraction, Luneau Technology, Bensenville, IL, US), and near stereoacuity (Pediatric Assessment of Stereopsis with a Smile; Vision Assessment Corp, Elk Grove Village, IL, US). Trained examiners, masked to refractive error status, administered the Test of Preschool Early Literacy (TOPEL; Print Knowledge, Definitional Vocabulary, and Phonological Awareness subtests; Pro-Ed, Austin, TX, US) and attention testing. Scores were compared between hyperopic and emmetropic groups and by magnitude of hyperopia and near visual function status, adjusting for age, sex, race/ethnicity, and parent's education. Participating children (mean age 58 months) included 244 hyperopes [mean, +3.8 ± standard deviation (SD) 0.8 D] and 248 emmetropes (+0.5 ± 0.5 D). Hyperopes performed significantly worse than emmetropes on the TOPEL overall (mean difference −4.3, $P = 0.01$) and TOPEL Print Knowledge (mean difference −2.4, $P = 0.007$) but not on TOPEL Definitional Vocabulary (mean difference −1.6, $P = 0.07$) or TOPEL Phonological Awareness (mean difference −0.3, $P = 0.39$). Hyperopic children with ≥4.0 D showed larger deficits in TOPEL scores as compared to emmetropes (mean difference −6.8, $P = 0.01$ for total score; mean difference −4.0, $P = 0.003$ for Print Knowledge). Compared to emmetropic children, hyperopic children with decreased near visual function (binocular near visual acuity of 20/40 or worse or near stereoacuity of 240 seconds or worse) showed the greatest deficits in TOPEL scores (with reduced near VA: mean difference −8.5, $P = 0.002$ for total score; mean difference −4.5, $P = 0.001$ for Print Knowledge; with reduced near stereoacuity: mean difference −8.6, $P < 0.001$ for total score; mean difference −5.3, $P < 0.001$ for Print Knowledge). Hyperopes (3 D to 6 D) also performed worse on sustained attention than emmetropes (mean difference −4.1; $P < 0.001$).[38] Greater differences were observed for hyperopes with reduced near visual acuity (20/40 or worse) (mean difference −6.4; $P < 0.001$) or reduced near stereoacuity (240 seconds of arc or worse) (mean difference −6.7; $P < 0.001$). Performance of hyperopes with better near visual function was generally similar to that of emmetropes.[37, 38]

Associations Between Hyperopia and Visual Function in the VIP-HIP Study

Mean visual acuities (distance and near), accommodative accuracy, and stereoacuity were compared between moderately hyperopic (3 D to 6 D) and emmetropic children.[39] Hyperopic children had worse mean (± SD) logMAR monocular distance visual acuities than emmetropic children (0.14 ± 0.11 vs 0.05 ± 0.10, $P < 0.001$ for the better eye; 0.19 ± 0.10 vs 0.10 ± 0.11, $P < 0.001$ for the worse eye) and worse mean binocular logMAR near visual acuity (0.21 ± 0.11 vs 0.13 ± 0.11, $P < 0.001$). Mean accommodative accuracy was worse in hyperopic than in emmetropic children (lags of 2.03 ± 1.03 D vs 1.03 ± 0.51 D, $P < 0.001$ for Monocular Estimation Method; 0.99 ± 1.0 D vs 0.46 ± 0.45 D, $P < 0.001$ for Grand Seiko). Median near stereoacuity was also worse in hyperopic than in emmetropic children (120 sec arc vs 40 sec arc, $P < 0.001$). Using the 95% confidence intervals of emmetropic children, each visual function was also classified as normal or reduced and

the percentages with reduced visual function in each group were compared. On average, a greater number of reduced visual functions were observed in moderately hyperopic than in emmetropic children (1.0 vs 0.19, $P < 0.001$).[39]

The impact of increasing uncorrected hyperopia on visual function was further investigated in a secondary analysis of all 4- and 5-year-old children who presented for VIP-HIP study eligibility testing (mean age 58 months).[40] Specifically, visual functions were compared among children classified as having emmetropia [<1 D spherical equivalent (SE) myopia or hyperopia], low hyperopia (+1 to <+3 D SE), or moderate hyperopia (+3 to +6 D SE). Children with amblyopia, strabismus, or 1 D or more of anisometropia or astigmatism were excluded. Mean spherical equivalent (± SD) for each group was +0.52 D (±0.49) for emmetropia (N = 270), +2.18 D (±0.57) for low hyperopia (N = 171), and +3.95 D (±0.78) for moderate hyperopia (N = 113). With increasing hyperopia, there was a consistent trend of decreasing visual function ($P < 0.001$). Mean distance logMAR visual acuity in the better eye decreased from emmetropic to low hyperopic to moderately hyperopic children (0.05 ± 0.10, 0.06 ± 0.10, 0.12 ± 0.11, respectively, $P < 0.001$). Mean (± SD) binocular near visual acuity also decreased with increasing hyperopia (emmetropia: 0.13 ± 0.11; low hyperopia: 0.15 ± 0.10; moderate hyperopia: 0.19± 0.11, $P < 0.001$). Although all children had age-normal distance VA, a logMAR (Snellen) visual acuity of 0.00 (6/6) or better (distance, near) was attained among a higher percentage of emmetropic (52%, 26%) and low hyperopic (47%, 15%) children than moderately hyperopic children (25%, 9%). Accommodative accuracy decreased with increasing hyperopia (correlation coefficient $P = 0.50$, $P < 0.001$). Median near stereoacuity also decreased with increasing hyperopia, from 40 seconds arc for emmetropes, to 60 seconds arc for low hyperopes, to 120 seconds arc for moderate hyperopes. The percentage of children in each group with 1 or more decreased visual functions increased with increasing hyperopia, from 17% of emmetropes, to 39% of low hyperopes, to 66% of moderate hyperopes.[40]

Future Research

Results of the VIP study have provided evidence-based vision screening protocols[10,11,48] which in turn has led in part to federal initiatives to increase the number of young children receiving vision screenings and exams. The VIP-HIP Study[37–40] showed the association between hyperopia and early literacy, attention, and near visual function. Other studies have also shown an association between hyperopia and reading.[49,50] However, little research exists on the effects of refractive error, especially hyperopia correction.[51–54] Future research is needed to determine the effect of hyperopic correction on early literacy, attention, and near visual function in order to develop evidence-based guidelines for correction of hyperopia in young children who do not have amblyopia and/or strabismus.

Acknowledgements:

The VIP and VIP-HIP studies were collaborative efforts of dedicated investigators across the country. The VIP Study Executive Committee consisted of: Paulette Schmidt, OD, MS (chair); Agnieshka Baumritter, MA; Elise Ciner, OD; Lynn Cyert, PhD, OD; Velma Dobson, PhD; Beth Haas; Marjean Taylor Kulp, OD, MS; Maureen Maguire, PhD; Bruce Moore, OD; Deborah Orel-Bixler, PhD, OD; Ellen Peskin, MA; Graham Quinn, MD, MSCE; Maryann Redford, DDS, MPH; Janet Schultz, RN, MA, CPNP; and Gui-shuang Ying, PhD. The VIP-HIP Executive Committee consisted of: Marjean Taylor Kulp, OD, MS (Study Co-Chair); Elise Ciner, OD (Study Co-Chair); Maureen Maguire, PhD; Bruce Moore, OD; Lynn Cyert, PhD, OD; Graham Quinn, MD, MSCE;

T. Rowan Candy, PhD; Jill Pentimonti, PhD, Gui-Shuang Ying, PhD and Maryann Redford, DDS, MPH (NEI Liaison). Velma Dobson, PhD also contributed to the design of the VIP-HIP study. We remember and are grateful for the countless contributions of Velma Dobson, our Scientific Advisor, to VIP. The complete listings of members of the VIP Study Group[10,11] and the VIP-HIP Study Group[37] have been published previously.

The VIP and VIP-HIP Studies were supported by the National Eye Institute of the National Institutes of Health, Department of Health and Human Services grants: U10EY12644, U10EY12547, U10EY12545, U10EY12550, U10EY12534, U10EY12647, U10EY12648, R21EY018908 and R01EY021141. The funding organization had no role in the design or conduct of this research.

References:

1. U.S. Public Health Service. Vision screening in children. Am Fam Physician. 1994;50:587–90. [PubMed: 8067325]
2. Ciner EB, Schmidt PP, Orel-Bixler D, et al. Vision screening of preschool children: evaluating the past, looking toward the future. Optom Vis Sci. 1998;75:571–584. [PubMed: 9734801]
3. Ying GS, Maguire MG, Cyert LA, et al. Prevalence of vision disorders by racial and ethnic group among children participating in head start. Ophthalmology. 2014;121:630–636. [PubMed: 24183422]
4. Jiang X, Tarczy-Hornoch K, Stram D, et al. Prevalence, characteristics, and risk factors of moderate or high hyperopia among multiethnic children 6 to 72 months of age: a pooled analysis of individual participant data. Ophthalmology. 2019;126:989–999. [PubMed: 30822446]
5. Tarczy-Hornoch K, Cotter SA, Borchert M, et al. Prevalence and causes of visual impairment in Asian and non-Hispanic white preschool children: Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology. 2013;120:1220–1226. [PubMed: 23561327]
6. Wen G, Tarczy-Hornoch K, McKean-Cowdin R, et al. Prevalence of myopia, hyperopia, and astigmatism in non-Hispanic white and Asian children: Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology. 2013;120:2109–2116. [PubMed: 23953098]
7. Multi-Ethnic Pediatric Eye Disease Study Group. Prevalence of myopia and hyperopia in 6- to 72-month-old African American and Hispanic children: the Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology. 2010;117:140–147. [PubMed: 19926137]
8. Giordano L, Friedman DS, Repka MX, et al. Prevalence of refractive error among preschool children in an urban population: the Baltimore Pediatric Eye Disease Study. Ophthalmology 2009;116:739–746. [PubMed: 19243832]
9. Friedman DS, Repka MX, Katz J, et al. Prevalence of amblyopia and strabismus in white and African American children aged 6 through 71 months the Baltimore Pediatric Eye Disease Study. Ophthalmology. 2009;116:2128–2134. [PubMed: 19762084]
10. Schmidt P, Maguire M, Dobson V, et al. Comparison of preschool vision screening tests as administered by licensed eye care professionals in the Vision In Preschoolers Study. Ophthalmology. 2004;111:637–650. [PubMed: 15051194]
11. Vision in Preschoolers Study Group. Preschool vision screening tests administered by nurse screeners compared with lay screeners in the vision in preschoolers study. Investigative ophthalmology & visual science. 2005;46:2639–2648. [PubMed: 16043831]
12. Ying GS, Maguire M, Quinn G, et al. ROC analysis of the accuracy of noncycloplegic retinoscopy, Retinomax Autorefractor, and SureSight Vision Screener for preschool vision screening. Investigative ophthalmology & visual science. 2011;52:9658–9664. [PubMed: 22125281]
13. Cyert L, Schmidt P, Maguire M, et al. Threshold visual acuity testing of preschool children using the crowded HOTV and Lea Symbols acuity tests. J AAPOS. 2003;7:396–399. [PubMed: 14730291]
14. Dobson V, Maguire M, Orel-Bixler D, et al. Visual acuity results in school-aged children and adults: Lea Symbols chart versus Bailey-Lovie chart. Optometry and vision science. 2003;80:650–654. [PubMed: 14502046]
15. Kulp MT, Dobson V, Peskin E, et al. The electronic visual acuity tester: testability in preschool children. Optometry and vision science. 2004;81:238–244. [PubMed: 15097765]

16. Kulp MT, Vision in Preschoolers Study Group. Findings from the Vision in Preschoolers (VIP) Study. Optometry and vision science. 2009;86:619–623. [PubMed: 19417714]
17. Vision in Preschoolers Study Group. Children unable to perform screening tests in vision in preschoolers study: proportion with ocular conditions and impact on measures of test accuracy. Investigative ophthalmology & visual science. 2007;48:83–87. [PubMed: 17197520]
18. Schmidt PP, Maguire MG, Moore B, et al. Testability of preschoolers on stereotests used to screen vision disorders. Optometry and vision science. 2003;80:753–757. [PubMed: 14627942]
19. Vision in Preschoolers Study Group. Preschool visual acuity screening with HOTV and Lea symbols: testability and between-test agreement. Optometry and vision science. 2004;81:678–683. [PubMed: 15365387]
20. Vision In Preschoolers Study Group. Impact of confidence number on the screening accuracy of the retinomax autorefractor. Optometry and vision science. 2007;84:181–188. [PubMed: 17435531]
21. Vision in Preschoolers Study Group. Does assessing eye alignment along with refractive error or visual acuity increase sensitivity for detection of strabismus in preschool vision screening? Investigative ophthalmology & visual science. 2007;48:3115–3125. [PubMed: 17591881]
22. Vision in Preschoolers Study Group. Impact of confidence number on accuracy of the SureSight Vision Screener. Optometry and vision science. 2010;87:96–103. [PubMed: 20061987]
23. Vision in Preschoolers Study Group, Schmidt P, Maguire M, et al. Random Dot E stereotest: testability and reliability in 3- to 5-year-old children. J AAPOS. 2006;10:507–514. [PubMed: 17189143]
24. Ying GS, Huang J, Maguire MG, et al. Associations of anisometropia with unilateral amblyopia, interocular acuity difference, and stereoacuity in preschoolers. Ophthalmology. 2013;120:495–503. [PubMed: 23174398]
25. Ying GS, Kulp MT, Maguire M, et al. Sensitivity of screening tests for detecting vision in preschoolers-targeted vision disorders when specificity is 94%. Optometry and vision science. 2005;82:432–438. [PubMed: 15894920]
26. Ciner E, Carter A, Ying GS, et al. Comparison of the Retinomax and Palm-AR Auto-Refractors: a pilot study. Optometry and vision science. 2011;88:830–836. [PubMed: 21516050]
27. Ciner EB, Ying GS, Kulp MT, et al. Stereoacuity of preschool children with and without vision disorders. Optometry and vision science. 2014;91:351–358. [PubMed: 24463769]
28. Huang J, Maguire MG, Ciner E, et al. Risk factors for astigmatism in the Vision in Preschoolers Study. Optometry and vision science. 2014;91:514–521. [PubMed: 24727825]
29. Huang J, Maguire MG, Ciner E, et al. Intertester agreement in refractive error measurements. Optometry and vision science. 2013;90:1128–1137. [PubMed: 23974664]
30. Kulp MT, Ying GS, Huang J, et al. Accuracy of noncycloplegic retinoscopy, retinomax autorefractor, and SureSight vision screener for detecting significant refractive errors. Investigative ophthalmology & visual science. 2014;55:1378–1385. [PubMed: 24481262]
31. Kulp MT, Ying GS, Huang J, et al. Associations between hyperopia and other vision and refractive error characteristics. Optometry and vision science. 2014;91:383–389. [PubMed: 24637486]
32. Maguire M, Ying GS, Ciner E, et al. Detection of significant hyperopia in preschool children using two automated vision screeners. Optometry and Vision Science. 2021. In press.
33. Pascual M, Huang J, Maguire MG, et al. Risk factors for amblyopia in the vision in preschoolers study. Ophthalmology. 2014;121:622–629. [PubMed: 24140117]
34. Schmidt P, Baumritter A, Ciner E, et al. Predictive value of photoscreening and traditional screening of preschool children. J AAPOS. 2006;10:377–378. [PubMed: 16935243]
35. Ciner EB, Dobson V, Schmidt PP, et al. A survey of vision screening policy of preschool children in the United States. Surv Ophthalmol. 1999;43:445–457. [PubMed: 10340562]
36. Cyert L, Ying GS, Dobson V, et al. Effect of Age Using Lea Symbols or HOTV for Preschool Vision Screening. Optometry Vision Sci. 2010;87:87–95.
37. VIP-HIP Study Group. Uncorrected hyperopia and preschool early literacy: results of the Vision in Preschoolers-Hyperopia in Preschoolers (VIP-HIP) Study. Ophthalmology. 2016;123:681–689. [PubMed: 26826748]

38. Kulp MT, Ciner E, Maguire M, et al. Attention and visual motor integration in young children with uncorrected hyperopia. Optometry and vision science. 2017;94:965–970. [PubMed: 28902771]
39. Ciner EB, Kulp MT, Maguire MG, et al. Visual Function of moderately hyperopic 4- and 5-year-old children in the Vision in Preschoolers - Hyperopia in Preschoolers Study. American journal of ophthalmology. 2016;170:143–152. [PubMed: 27477769]
40. Ciner EB, Kulp MT, Pistilli M, et al. Associations between visual function and magnitude of refractive error for emmetropic to moderately hyperopic 4-and 5-year-old children in the Vision in Preschoolers - Hyperopia in Preschoolers Study. Ophthal Physl Opt. 2021;41:553–564.
41. Vision In Preschoolers Study Group. Development and implementation of a preschool vision screening program in a mobile setting. NHSA Dialog. 2005;8:16–24.
42. Wu YF, Thibos LN, Candy TR. Two-dimensional simulation of eccentric photorefraction images for ametropes: factors influencing the measurement. Ophthal Physl Opt. 2018;38:432–446.
43. Harvey EM, Dobson V, Clifford-Donaldson CE, et al. Prevalence of astigmatism in Native American infants and children. Optometry and vision science. 2010;87:400–405. [PubMed: 20386351]
44. Multi-Ethnic Pediatric Eye Disease Study Group. Prevalence of amblyopia and strabismus in African American and Hispanic children ages 6 to 72 months the multi-ethnic pediatric eye disease study. Ophthalmology. 2008;115:1229–1236. [PubMed: 17953989]
45. McKean-Cowdin R, Cotter SA, Tarczy-Hornoch K, et al. Prevalence of amblyopia or strabismus in Asian and non-Hispanic white preschool children: Multi-Ethnic Pediatric Eye Disease Study. Ophthalmology. 2013;120:2117–2124. [PubMed: 23697956]
46. Chia A, Dirani M, Chan YH, et al. Prevalence of amblyopia and strabismus in young singaporean chinese children. Investigative ophthalmology & visual science. 2010;51:3411–3417. [PubMed: 20207979]
47. Dirani M, Chan YH, Gazzard G, et al. Prevalence of refractive error in Singaporean Chinese children: the strabismus, amblyopia, and refractive error in young Singaporean Children (STARS) study. Investigative ophthalmology & visual science. 2010;51:1348–1355. [PubMed: 19933197]
48. Cotter SA, Cyert LA, Miller JM, et al. Vision screening for children 36 to <72 months: recommended practices. Optometry and vision science. 2015;92:6–16. [PubMed: 25562476]
49. Shankar S, Evans MA, Bobier WR. Hyperopia and emergent literacy of young children: pilot study. Optometry and vision science. 2007;84:1031–1038. [PubMed: 18043422]
50. Eames TH. The influence of hypermetropia and myopia on reading achievement. American journal of ophthalmology. 1955;39:375–377. [PubMed: 14350052]
51. Roch-Levecq AC, Brody BL, Thomas RG, Brown SI. Ametropia, preschoolers' cognitive abilities, and effects of spectacle correction. Archives of ophthalmology. 2008;126:252–258. [PubMed: 18268218]
52. Rosner J, Rosner J. The relationship between moderate hyperopia and academic achievement: how much plus is enough? Journal of the American Optometric Association. 1997;68:648–650. [PubMed: 9354056]
53. Slavin RE, Collins ME, Repka MX, et al. In plain sight: reading outcomes of providing eyeglasses to disadvantaged children. J Educ Students Plac. 2018;23:250–258.
54. Neitzel AJ, Wolf B, Guo X, et al. Effect of a randomized interventional school-based vision program on academic performance of students in grades 3 to 7: a cluster randomized clinical trial. JAMA ophthalmology. 2021;39:1104–1114.

Table 1.

Prevalence of Each Type of Refractive Error by Racial/Ethnicity Group

	African American (N=2072) Prevalence (%) (95% CI)	American Indian (N=343) Prevalence (%) (95% CI)	Asian (N = 145) Prevalence (%) (95% CI)	Hispanic (N = 796) Prevalence (%) (95% CI)	Non-Hispanic White (N=481) Prevalence (%) (95% CI)
Myopia	1.55 (0.99–2.11)	0.16 (0.00–0.47)	1.93 (0.00–4.20)	1.34 (0.71–1.97)	0.78 (0.00–1.60)
Hyperopia	6.79 (5.67–7.92)	8.89 (5.26–12.5)	5.47 (2.49–8.45)	6.87 (4.79–8.95)	11.9 (8.25–15.6)
Astigmatism	8.41 (7.02–9.80)	4.28 (2.11–6.44)	7.62 (3.82–11.4)	11.1 (8.41–13.8)	6.79 (3.90–9.68)
Anisometropia	4.34 (3.42–5.26)	3.25 (1.39–5.10)	2.65 (0.86–4.44)	7.13 (5.20–9.07)	5.48 (2.74–8.22)

CI indicates confidence interval.

Table 2.

Summary of Selected Key Outcomes From the VIP and VIP-HIP Studies

• Retinomax Autorefraction or crowded Lea Symbols Visual Acuity at 5 feet along with their associated VIP referral criteria[10,11] can be used by trained screeners (nurse, lay, or eyecare provider) to effectively identify preschool children with vision disorders (amblyopia, strabismus, significant refractive error, and/or unexplained visual acuity).
• Eyecare providers can also use noncycloplegic retinoscopy for vision screening.[10]
• Autorefractors were more accurate and performed significantly better than photoscreeners for identifying children with vision disorders.[10]
• Children should be referred for a comprehensive vision examination if they meet the associated VIP referral criteria in 1 or both eyes[10,11], or if they are unable to complete a VIP screening test (Retinomax, stereoacuity, or visual acuity).[17]
• Meaningful deficits in early literacy and attention were observed in uncorrected, moderately hyperopic children as compared to emmetropic children. The greatest deficits were observed in hyperopic children with deficits in near visual function.[37,38]
• Increasing magnitude of hyperopia was associated with worsening near visual function (near visual acuity, near stereoacuity, accommodative accuracy). [39 40]