# Visual Morbidity Due to Inaccurate Spectacles among School Children in Rural China: The See Well to Learn Well Project, Report 1

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**PURPOSE.** Inadequately corrected refractive error is the leading cause of visual disability among children in China; inaccurate spectacles are a potential cause. The prevalence and visual impact of spectacle inaccuracy were studied among rural, secondary-school children, to determine the optimal timing for updating of refraction.

**METHODS.** A random sample of children from years 1 and 2 in all junior and senior high schools in Fuyang Township, Guangdong Province, underwent ocular examination. All children who reported wearing glasses received cycloplegic refraction, vision assessment, and measurement of current spectacles.

**RESULTS.** Among 3226 examined children, 733 (22.7%) reported owning spectacles. Refractive error and spectacle power were assessed for 588 (80.2%) children. They had a mean age of 15.0 ± 1.6 years; 70.2% were girls, 83.3% had more than −1.5 D of myopia, and 17.9% had presenting vision ≤ 6/12 in the better eye. The glasses of 48.8% of children were inaccurate by ≥1 D; inaccuracy was ≥2 D in 17.7%. Children with inaccurate glasses (≥1 D) had presenting vision in the better eye significantly ($P < 0.001$) worse than that of children with accurate glasses, and 30.3% had presenting acuity ≤ 6/12. In multivariate models, younger age ($P = 0.004$), more myopic refractive error ($P < 0.001$), and having glasses ≥ 1 year old ($P = 0.04$) were associated with inaccurate spectacles.

**DISCUSSION.** Inaccurate spectacles are common and are associated with significant visual impairment among children in rural China. Reducing outdated glasses could lessen the visual burden, although refractive services may have to be offered on an annual basis for optimal benefit. (*Invest Ophthalmol Vis Sci.* 2009;50:2011–2017) DOI:10.1167/iovs.08-2849

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Inadequately corrected refractive error is the leading cause of visual impairment among preschool,[1] primary-school,[2] and secondary-school[3,4] children in China. While failure to own and wear spectacles is clearly an important factor,[5] our previous work suggests that the wear of inaccurate spectacles also contributes to the visual burden.[5]

The scope of the problem is substantial: while some 60% of secondary school children in rural China are myopic,[3,4] nearly two-thirds of those who could benefit from spectacles do not have adequate correction.[3,5] More than 90% of visual impairment among Chinese school children is due to refractive error.[3,4]

Few studies have been attempted to systematically document the accuracy of children's currently worn spectacles. Robaei et al.[6] found that 38.3% of Australian children examined on a population basis who were wearing glasses had no measurable refractive error in either eye. Among children given spectacles in a school-based program in Oaxaca, Mexico, 23% were subsequently found to have 6/6 uncorrected vision bilaterally.[7] Among secondary school children wearing their own glasses at the time of examination in rural China and whose vision could be improved to ≤6/12 with refraction, 25.1% were wearing spectacles that did not improve their vision to at least 6/12.[5]

On the basis of these limited data, it appears likely that many children are wearing glasses that do not improve their vision optimally. This fact is of particular concern, given recent reports that correction of even modest refractive errors can significantly improve self-reported visual function.[7,8] Important questions remain, however, for program planners seeking to reduce the burden of visual disability due to inaccurate glasses. What is the role of incorrect refractive practice, as opposed to initially correct, but now outdated glasses, in the problem of inaccurate spectacles? The former demands training programs to improve the accuracy of refraction, but the latter can only be addressed through more regular provision and uptake of services.

In this study, we performed cycloplegic refraction and measured current spectacle power among children who reported owning glasses in an ongoing school-based program in the rural Chaoshan region of Guangdong Province, China. Self-reported age of currently worn spectacles was also recorded. The purposes of the study were to:

1. Document the prevalence and visual impact of inaccurate spectacles among rural Chinese secondary-school children.
2. Assess the role of several potential determinants of inaccurate glasses, including spectacle age.
3. Provide an evidential basis for the optimal timing of provision of refractive services to reduce the visual burden of inadequately corrected refractive error in this region.

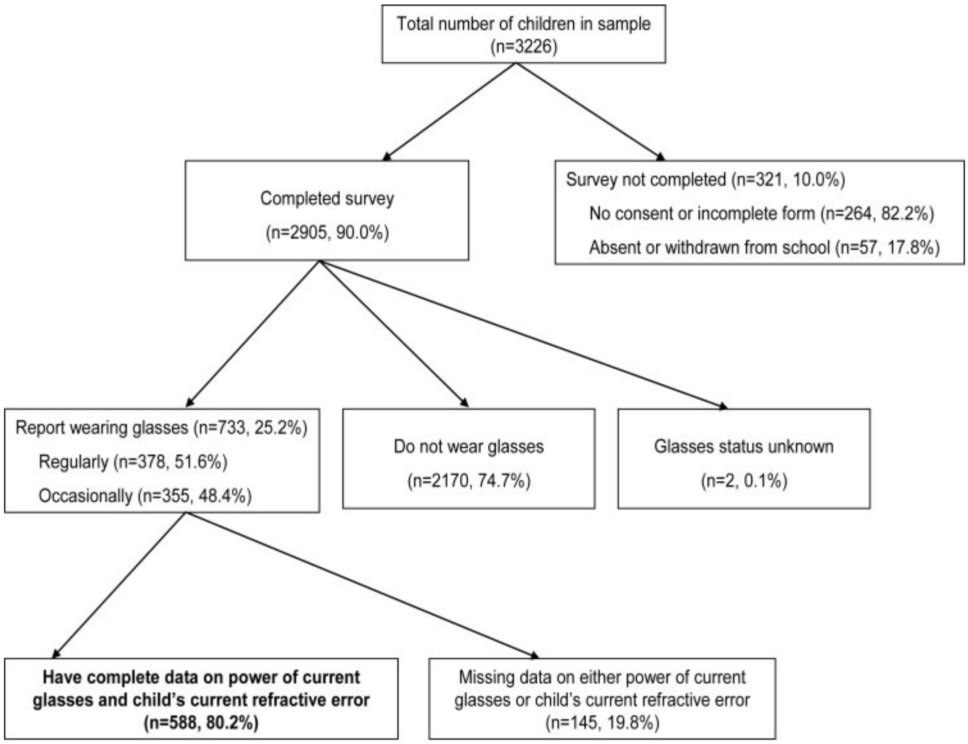


**FIGURE 1.** Flowchart showing enrollment of subjects in the present study.

## METHODS

The See Well to Learn Well Project is an on-going randomized trial of interventions to promote spectacle wear among 10,000 secondary school children in three towns in the rural Chaoshan region of southern China. Participants are selected at random from year 1 and year 2 classes at all junior and senior high schools in the area. Written informed consent is obtained from at least one parent of all participants, and the protocol has been approved in full by Ethics Committees at the Chinese University of Hong Kong and the Joint Shantou International Eye Center (Guangdong Province, China) and the Declaration of Helsinki has been adhered to throughout.

### Subjects

All year 1 and year 2 classes (average size, ~60 children) in the five Junior High Schools and one Senior High School of Fuyang Township, Guangdong Province, were enumerated and classes were selected at random from a list of all eligible classes at each school until a total of 600 children (usually 8 to 10 classes) had been identified in the sampling frame. Our pilot testing in the area had demonstrated that participation rates were on the order of 80% to 85%, meaning that 600 children in the sampling frame would be sufficient to guarantee our target figure of 500 children examined at each school.

Letters describing the study and offering the choice to participate or not were distributed to parents of all children in selected classes. Study personnel informed each participating class on the day before examination that all children owning spectacles were requested to bring them to school the next day. At the time of examination, the children reporting that they wore glasses either regularly or occasionally underwent cycloplegic refraction and measurement of glasses power. The children who reported wearing glasses but failed to bring them to school were asked to bring the glasses later that same day or the next for measurement.

### Data Collection

Among 3226 children in the sample frame, 2905 (90.0%) completed the questionnaires and examination (Fig. 1). Written questionnaires were administered to the children detailing age, sex, parental education, and frequency of spectacle wear. Subjects reporting wearing glasses ($n$ = 733, 25.2%, Fig. 1) were also asked to state when the currently worn spectacles were purchased and what they estimated that their families were willing to pay for spectacles. The questionnaire also included a Chinese translation of an instrument developed originally by Fletcher et al., [9] to assess self-reported visual function in rural Asia. This instrument has been validated for use in Chinese[10,11] and is described elsewhere in detail.[9] The questionnaire could be administered in 5 to 10 minutes. The overall scale score ranged from 0 (worst) to 100 (best).[9]

Visual acuity with and without habitual refraction if available was measured by trained study personnel in well-lighted areas of the school during daylight hours, at a distance of 5 m, separately in each eye of each child. The children who did not have their spectacles at school were asked to bring them for vision assessment on a separate day, and vision was recorded both with and without glasses. Identical illuminated Snellen tumbling E vision charts (Shantou City Medical Equipment Ltd., Shantou, China) was used for all testing. The nontested eye was covered by the subject using a hand-held occluder, with proper occlusion and neutral head position monitored by the examiner. The right eye was tested first. A single optotype of each size was presented first, starting at 6/30. If a letter was not correctly identified, testing began two lines above, with the child being asked to read all optotypes on the line sequentially. A subject had to identify correctly more than half of the letters on a given line (e.g., three of five, four of six) to be considered to have achieved that level of acuity.

Subjects who reported wearing spectacles underwent cycloplegic autorefraction (Potec PRK-5000; Potec, Co. Ltd., Seoul, Korea) with subjective refinement by an ophthalmologist in each eye, at least 30 minutes after receiving cyclopentolate 1% one drop to both eyes every 5 minutes for a total of two drops in each eye. The power of subjects' current spectacles was measured bilaterally (Topcon CL-100; Topcon Corp., Tokyo, Japan).

### Statistical Methods

The $\chi^2$ test was used to compare group differences for categorical variables. For continuous variables, group differences were compared by two-tailed Student's $t$-test, with data summarized as the mean (SD),

**Table 1.** Demographic Characteristics, Vision, and Visual Function for Children Reporting Glasses Wear for Whom There Were or Were Not Complete Data for Refractive Error and Spectacle Power

| | Total Reporting Glasses Wear ($n$ = 733) | Data Complete ($n$ = 588, 80.2%) | Data Incomplete ($n$ = 145, 19.8%) | *P*† |
|---|---|---|---|---|
| Age (y)* | 14.9 (1.5) | 15.0 (1.6) | 14.3 (1.2) | <0.001 |
| Sex | | | | |
| Male | 241 (32.9) | 174 (29.6) | 67 (46.2) | <0.001 |
| Female | 491 (67.0) | 413 (70.2) | 78 (53.8) | |
| Missing | 1 (0.1) | 1 (0.2) | — | |
| Parents' highest education | | | | |
| Primary or below | 139 (19.0) | 117 (19.9) | 22 (15.2) | 0.044 |
| Junior school | 364 (49.7) | 300 (51.0) | 64 (44.1) | |
| High school | 170 (23.2) | 125 (21.3) | 45 (31.0) | |
| College or above | 26 (3.5) | 19 (3.2) | 7 (4.8) | |
| Missing | 34 (4.6) | 27 (4.6) | 7 (4.8) | |
| Uncorrected vision in the better eye | | | | |
| ≤6/12 | 579 (79.0) | 520 (88.4) | 59 (40.7) | <0.001 |
| >6/12 | 152 (20.7) | 67 (11.4) | 85 (58.6) | |
| Missing | 2 (0.3) | 1 (0.2) | 1 (0.7) | |
| Presenting vision in the better eye | | | | |
| ≤6/12 | 154 (21.0) | 105 (17.9) | 49 (33.8) | <0.001 |
| >6/12 | 579 (79.0) | 483 (82.1) | 96 (66.2) | |
| Visual function score* | 68.4 (15.6) | 67.4 (14.9) | 72.4 (17.5) | 0.001 |

Data are count (%), except as noted.
* Mean (SD).
† *P* for the comparison between children with complete data and those without.

or the Mann-Whitney *U* test, with data expressed as the median (interquartile range) for skewed variables. Uncorrected, presenting and best corrected vision in the better eyes (the Snellen decimal fraction) were minus log-transformed (i.e., log of the minimum angle of resolution, logMAR) to correct skewness before statistical analyses, but the untransformed numbers are presented in tables for the sake of clarity. In addition, multivariate logistic regression was performed to examine factors potentially associated with wearing inaccurate spectacles. Relevant odds ratio (OR) and respective 95% confidence interval (CI) were presented.

The following formula[12,13] was used to calculate the vector difference in diopters between the cycloplegic refraction in the better-seeing eye and the power of current spectacles in the same eye:

$$\text{Vector dioptric distance} = \sqrt{(2)} \times \sqrt{[(SE_{refraction} - SE_{glasses})^2 + (J0_1 - J0_2)^2 + (J45_1 - J45_2)^2]},$$

where

$$SE = \text{spherical equivalent refractive error (sphere + cylinder/2)}$$

$$J0 = -(\text{sphere power}/2) \times \cos(2 \times \text{axis})$$

$$J45 = -(\text{cylinder power}/2) \times \sin(2 \times \text{axis}).$$

Significance was defined by a two-sided $\alpha \leq 0.05$. All statistical analyses were performed with the use of commercial software (SPSS, ver. 14.0; SPSS, Inc., Chicago, IL).

## Results

Among the 733 children who reported wearing spectacles regularly or occasionally (25.2% of the examined subjects, Fig. 1), 588 (80.2%, Fig. 1) had complete data for refractive error and spectacle power and form the basis for the remaining analyses. Among the children with missing data, 12 had incomplete data on refractive error, 90 were lacking information on spectacle power, and 43 were missing both.

The children with complete data had a mean age of 15.0 ± 1.6 years, 413 (70.2%) were girls, and 105 (17.9%) had vision ≤ 6/12 in the better-seeing eye (Table 1). Participating children were older by approximately 8 months ($P < 0.001$), were more likely to be girls ($P < 0.001$), and had worse uncorrected vision and visual function ($P \leq 0.001$ for both) than eligible children without complete data (Table 1). Spherical equivalent refractive error in the better-seeing eye was more myopic than −1.5 D in 83.3% of the subjects (Fig. 2). Among the children wearing spectacles, 3.7% (27/733) had uncorrected 6/6 vision in both eyes.

The children's refractive error was significantly more myopic than was the spectacle power (mean difference, −0.88 ± 1.40 D, $P < 0.001$; Fig. 3). A difference (absolute value) of ≥1 D was present in 48.8% of spectacles, 17.7% of glasses were inaccurate by ≥2 D, and 6.1% of children had glasses that were inaccurate by 3 D or more.

The children wearing spectacles that were inaccurate by ≥1 D had significantly worse ($P < 0.001$) presenting vision in the better-seeing eye than did those with accurate spectacles (Table 2), and 30.3% had presenting vision ≤6/12. Those with inaccurate glasses were also younger ($P = 0.04$), had more myopic refractive error by >1 D ($P < 0.001$) and were significantly more likely to have had glasses for ≥1 year ($P = 0.005$, Table 2). Sex, parental education, frequency of spectacle wear, and the child's estimate of family willingness to pay for glasses were not associated with spectacle accuracy. In multiple logistic regression models, younger age, more myopic spherical equivalent, and having older glasses were all associated with wearing inaccurate spectacles; the children wearing glasses ≥ 1 year old had nearly 50% increased odds of owning inaccurate glasses (Table 3). The accuracy level generally declined monotonically with time (Fig. 4).

## Discussion

The importance of presenting visual acuity as an index of visual disability has been receiving growing attention.[14,15] Using presenting visual acuity allows program planners to better assess

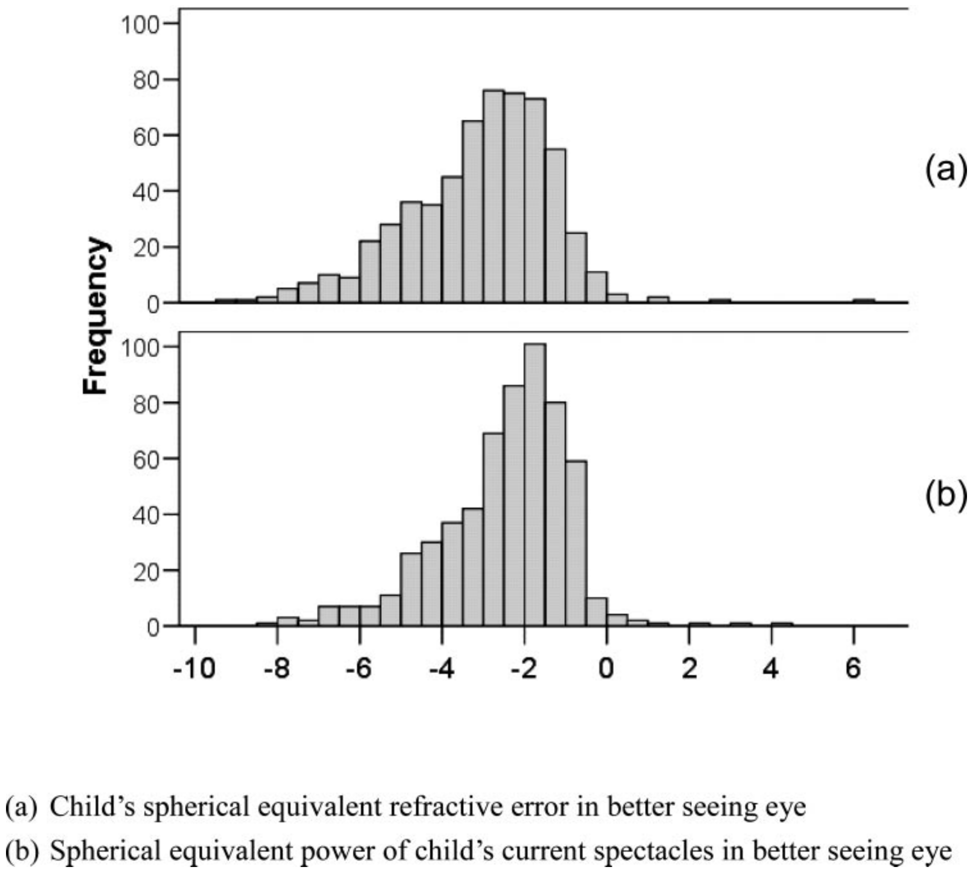


**Figure 2.** Distribution of cycloplegic refractive error (spherical equivalent in the better-seeing eye) and measured spectacle power in the better-seeing eyes of 588 children wearing glasses and with complete refraction and glasses power data.

the full scope of vision impairment existing in a community, in that persons with uncorrected refractive error are included. Recent estimates suggest that between 117[14] and 153[16] million people are visually impaired due to refractive error, representing 38% to 49%[14,16] of all global visual impairment. The annual direct cost of correcting refractive error in the United States alone has been estimated at US$ 3.8 billion.[17] Although traditional practice has generally not considered persons with uncorrected or undercorrected refractive error to be visually impaired, several experts now agree[14,15,18] that this approach leads to a significant underestimate of visual impairment. Dandona and Dandona,[18] for example, have argued strongly for a revision of the International Statistical Classifications of Disease (ICD) definitions to establish presenting visual acuity, rather than best corrected vision, as the standard for determining blindness and moderate visual impairment. As they state, the use of presenting vision in this setting "seems more appropriate for estimating and tracking visual impairment in the countries and regions of the world." McCarty and Taylor[15] have expressed agreement with this suggested approach.

Our results suggest that inaccurate spectacles contribute to the burden of inadequately corrected refractive error and impaired presenting vision. The wear of inaccurate spectacles was common in this rural Chinese secondary school population and was associated with a significant decrement in visual acuity when compared with the vision achieved with accurate glasses. Our result showing 17.9% of spectacle-wearing secondary-school children with presenting vision in the better eye ≤6/12 may be compared to 26.9% with vision at the same level in either eye among a similar-aged cohort reported from the NHANES (National Health and Nutrition Examination Survey).[19] The burden is financial as well as visual. It has been estimated that the annual cost of inaccurate glasses would be as high as US$200 million for preschool children alone if widespread vision screening were implemented in this age group.[20]

The proportion of children wearing spectacles without apparent visual need is less in our Chinese cohort than was reported in Australia[6] or rural Mexico,[7] as might be expected. Because of the higher prevalence of refractive error in China, the positive predictive value of a given refraction test is higher for any given level of test accuracy.

Younger age and more myopic refractive error were associated with wearing inaccurate spectacles in multiple regression models. A likely explanation for this is that refractive error changes more rapidly in younger children and those with greater baseline myopia, causing spectacles to become outdated more quickly. However, our finding with perhaps the greatest potential for corrective program intervention is the association between older spectacles and inaccuracy. A cutoff of 1 year appeared to discriminate reasonably well: The majority of spectacles purchased within the last year were accurate to within 1 D, whereas most that were purchased more than a year ago were not accurate (Fig. 4). The bulk of inaccurate glasses had insufficient myopic correction when compared to cycloplegic refraction in the better eye (Fig. 3), a finding that is consistent with the hypothesis that these adolescent Chinese children are continuing to grow more myopic after provision of their most recent pair of spectacles. Both the prevalence[21] and rate of progression[22] of myopia among ethnically Chinese children are among the highest in the world.

The challenge of providing sufficiently regular refractive services to reduce the burden of vision disability from outdated spectacles in China is somewhat daunting. A high proportion of Chinese children who could benefit from refractive correction are without any glasses at all,[3,4] and even in the United States, with annual expenditures in

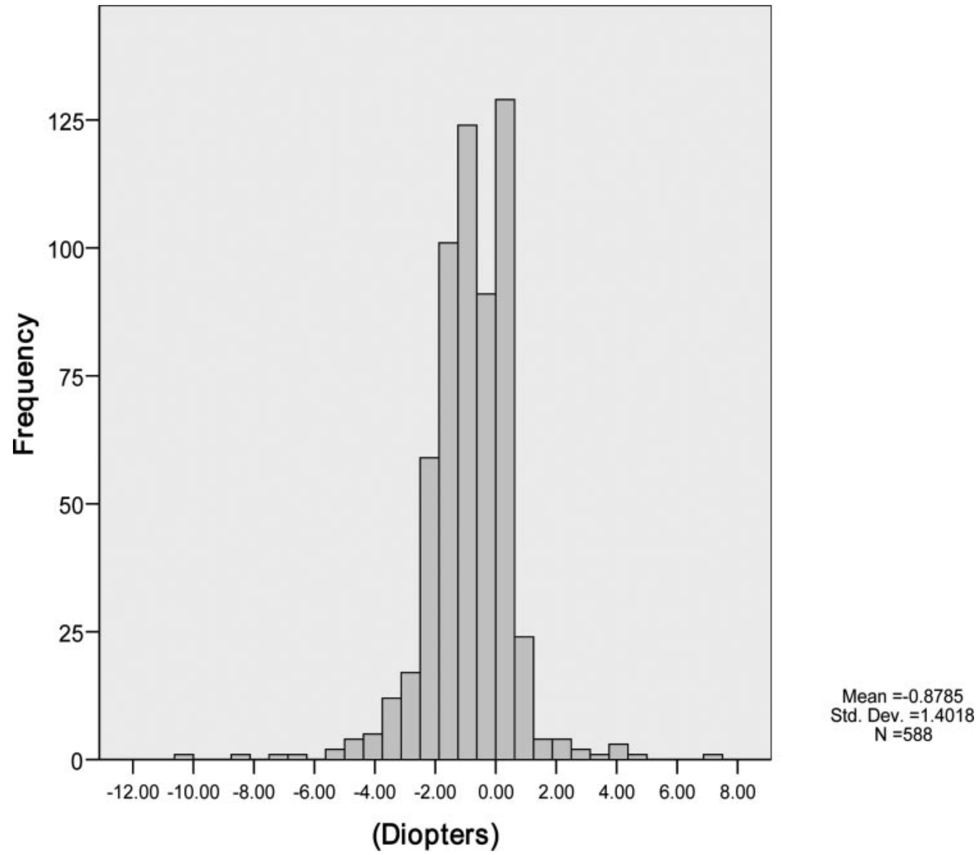


**FIGURE 3.** Difference between current spectacle power and cycloplegic refraction in the better-seeing eye for 588 children wearing glasses and with complete refraction and glasses power data. A negative value indicates that the child's refraction in the eye was more myopic or less hyperopic than the spectacle power in the eye, whereas a positive value means that the child's refraction was more hyperopic or less myopic than the spectacle power.

excess of US$3 billion,[17] a significant problem remains with inaccurate spectacles.[19] Suggestions to improve the penetration or reduce the cost of refractive services have included shifting from a clinical to a public health approach,[23] training paraprofessionals as refractionists,[24] wider utilization of self-refracting devices,[25] and cost recovery from the sale of spectacles.[26,27] More research in the setting of controlled trials is needed to demonstrate which of these ap-

**TABLE 2.** Characteristics of Children with Accurate (Power of Glasses within ±1 D of True Refractive Error in the Better-Seeing Eye) and Inaccurate Spectacles

| | Accurate ($n$ = 301) | Inaccurate ($n$ = 287) | $P$ |
|---|---|---|---|
| Age (y)* | 15.2 (1.6) | 14.9 (1.5) | 0.04 |
| Sex | | | |
| Male | 98 (32.6) | 76 (26.5) | 0.10 |
| Female | 202 (67.1) | 211 (73.5) | |
| Missing | 1 (0.3) | — | |
| Parents' highest education | | | |
| Primary or below | 59 (19.6) | 58 (20.2) | 0.84 |
| Junior school | 156 (51.8) | 144 (50.2) | |
| High school | 59 (19.6) | 66 (23.0) | |
| College or above | 10 (3.3) | 9 (3.1) | |
| Missing | 17 (5.6) | 10 (3.5) | |
| Presenting vision in the better eye*† | 0.93 (0.23) | 0.69 (0.25) | <0.001 |
| Child's spherical equivalent in the better eye* | −2.67 (1.55) | −3.74 (1.82) | <0.001 |
| Age of current glasses | | | |
| <1 year | 138 (45.8) | 98 (34.1) | 0.005 |
| ≥1 year | 133 (44.2) | 156 (54.4) | |
| Missing | 30 (10.0) | 33 (11.5) | |
| Self-reported frequency of glasses wear | | | |
| Regular | 157 (52.2) | 168 (58.5) | 0.120 |
| Occasional | 144 (47.8) | 119 (41.5) | |
| Amount willing to pay for glasses (US$)‡ | 28.60 (17.10–28.60) | 28.60 (17.10–28.60) | 0.91 |

Data are count (%), except as noted.

* Mean (SD)

† Vision is reported as the decimal equivalent of the Snellen fraction. The log of the inverse of this value (logMAR) is used for all statistical analyses, but the untransformed value is presented here for clarity.

‡ Median (interquartile range).

**TABLE 3.** Logistic Regression Model of Potential Predictors for Wearing Inaccurate Spectacles among 588 Secondary School Children in Rural China

| Independent Variables | Odds Ratio (95% CI) for Multivariate Analysis | *P* for Multivariate Analysis |
|---|---|---|
| Age (per year) | 0.83 (0.73–0.94) | 0.004 |
| Sex | | |
| Male* | | |
| Female | 1.32 (0.87–2.02) | 0.196 |
| Child's spherical equivalent in the better eye (per diopter) | 0.70 (0.62–0.79) | <0.001 |
| Age of current glasses | | |
| <1 year* | | |
| ≥1 year | 1.49 (1.00–2.21) | 0.048 |

* Reference group for analyses involving categorical variables.

proaches can most effectively broaden the reach of timely refractive correction in rural Asia.

The fact that 30% to 40% of spectacles were found to be inaccurate by ≥1 D even at <6 months after purchase suggests that training programs to improve the quality of refraction may also be needed. It should also be noted, however, that some clinical circumstances, such as anisometropia, may dictate giving less than the full myopic power indicated by refraction.

This report from the See Well to Learn Well Project must be taken within the context of its limitations. In the first place, there are fundamental limits to the accuracy of refractive error measurement. It has been reported that the reproducibility of subjective refraction is approximately 0.5 D for myopia, hyperopia, and astigmatism,[28,29] with a 95% CI of 0.6 D.[30] These values are less than the cutoff of 1 D of inaccuracy, which we chose for most of our analyses.

Although our protocol called for cycloplegia in both eyes of all refracted subjects, the possibility cannot be excluded that cycloplegia was incomplete in some children. Errors with noncycloplegic autorefraction in school-aged children have been reported to be in the range of −0.84 to −1.23 D,[31,32] with more myopic refractive error in noncyclopleged eyes.[31,32] The error generally appears to decrease with age[31] and is also less in myopes than in hyperopes.[32] Zhao et al.[32] have reported inaccuracy due to noncycloplegia of only −0.41 D in children aged 7 to 18 years with −2 D or more of myopia. Some three quarters of our subjects had myopia in this range in the study eye.

Our study was not truly population based. We included all schools in the area and compulsory education through the end of junior high school with reported attendance rates of > 90%[33] exists in this region. However, senior high school students (roughly a sixth of our sample) represent a more educated minority, and as such are likely to have a higher prevalence of myopia than the population at large. We found that children with greater degrees of myopia had less accurate spectacles, indicating that our findings for high school students may have overestimated the burden of inaccurate spectacles in the community at large. We also found that the one fifth of children with incomplete data, when compared with participants, were significantly younger (which would tend to yield an underestimate of spectacle inaccuracy) and less myopic

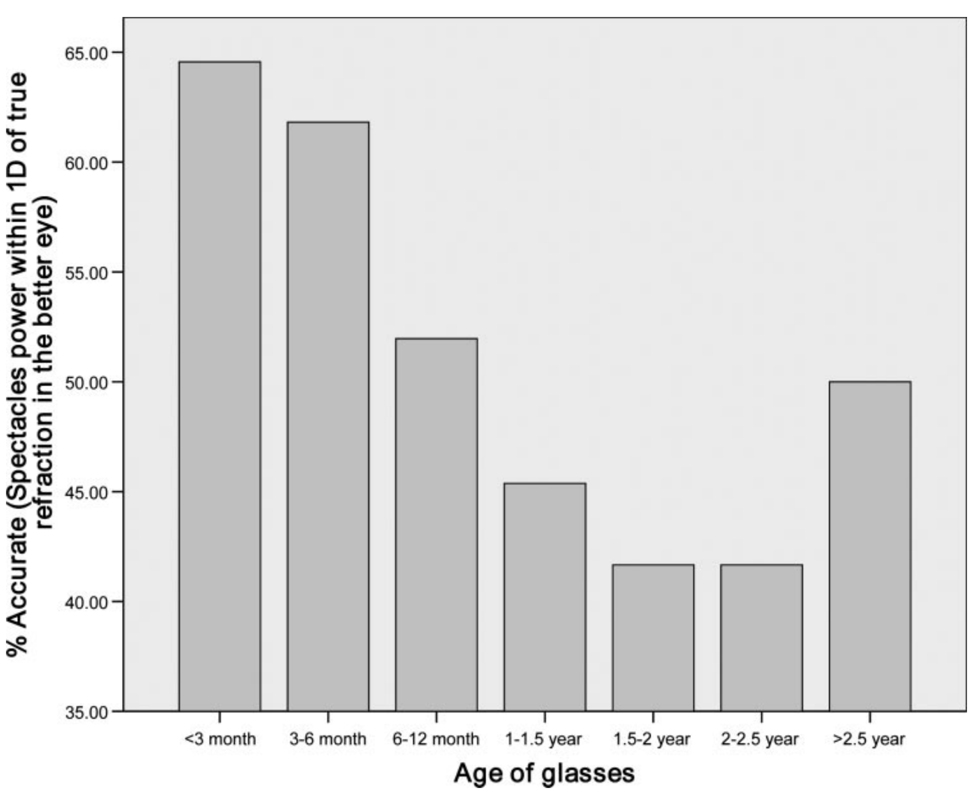


**FIGURE 4.** Spectacle accuracy (proportion of children with absolute power of vector difference between cycloplegic refraction and power of current spectacles in the better-seeing eye ≤ 1 D) as a function of self-reported spectacle age (duration of glasses wear) in 525 children with complete data (refraction, spectacle power, and spectacle age).

(yielding an overestimate). For all these reasons, our results may be applied to the population of similarly aged children only with caution. This issue is further exacerbated by very significant regional differences in socioeconomic status and access to refractive services throughout China, which tend to result in different levels of glasses wear and probable different rates of spectacle accuracy.

Finally, information obtained from children on topics such as familial willingness to pay for spectacles may be of less than complete reliability.

Nonetheless, this report from the See Well to Learn Well Project provides some of the first detailed data on the prevalence, predictors, and visual impact of inaccurate spectacles in a population with a very large burden[1–5] of inadequately corrected refractive error. These results outline the role of outdated spectacles in this problem, and provide program planners with data that may be used to plan optimal timing for delivery of refractive services.

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