Myopia, Spectacle Wear, and Risk of Bicycle Accidents Among Rural Chinese Secondary School Students

The Xichang Pediatric Refractive Error Study Report No. 7

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Objective: To study the effect of myopia and spectacle wear on bicycle-related injuries in rural Chinese students. Myopia is common among Chinese students but few studies have examined its effect on daily activities.

Methods: Data on visual acuity, refractive error, current spectacle wear, and history of bicycle use and accidents during the past 3 years were sought from 1891 students undergoing eye examinations in rural Guangdong province.

Results: Refractive and accident data were available for 1539 participants (81.3%), among whom the mean age was 14.6 years, 52.5% were girls, 26.8% wore glasses, and 12.9% had myopia of less than –4 diopters in both eyes. More than 90% relied on bicycles to get to school daily. A total of 2931 accidents were reported by 423 participants, with 68 requiring medical attention. Male sex (odds ratio, 1.55; $P<.001$) and spectacle wear (odds ratio, 1.38; $P=.04$) were associated with a higher risk of accident, but habitual visual acuity and myopia were unassociated with the crash risk, after adjusting for age, sex, time spent riding, and risky riding behaviors.

Conclusion: These results may be consistent with data on motor vehicle accidents implicating peripheral vision (potentially compromised by spectacle wear) more strongly than central visual acuity in mediating crash risk.

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Uncorrected refractive error accounts for more than 95% of visual impairment among children in rural China.[1,2] Among rural Chinese secondary schoolchildren, 16% to 20% have habitual visual acuity of no better than 6/12 in at least 1 eye.[1,2] Although it has been demonstrated that myopia is associated with significant decrements in self-reported visual function[2] and that correction of even modest amounts of refractive error significantly improves functioning,[3] few reports have examined the extent to which uncorrected refractive error and the resulting visual impairment may affect the daily activities of children.

Unintentional injuries are the leading cause of mortality among children of all ages in the United States[4] and among adolescents worldwide.[5] Injuries associated with bicycle riding are of particular concern; riding a bicycle was the single most common exposure for leisure-time and traffic-related injuries in a recent German study of children and adolescents.[6] Children younger than 15 years have the highest rates of bicycle-related injuries among any age group.[7-9] In 2003, an estimated 10 700 children were hospitalized in the United States for a bicycle-related injury, at a total cost of US $200 million for in-patient treatment alone.[9]

In China, the burden of bicycle-related injuries appears to be even greater. A study from Wuhan concluded that mortality rates for Chinese cyclists exceed those in the United States by 7-fold.[10] Bicyclists in China are the most common traffic fatalities, constituting 45% of the total,[10] and bicycle accidents are the leading cause of brain injury.[11]

The Xichang Pediatric Refractive Error Study (X-PRES) is a school-based

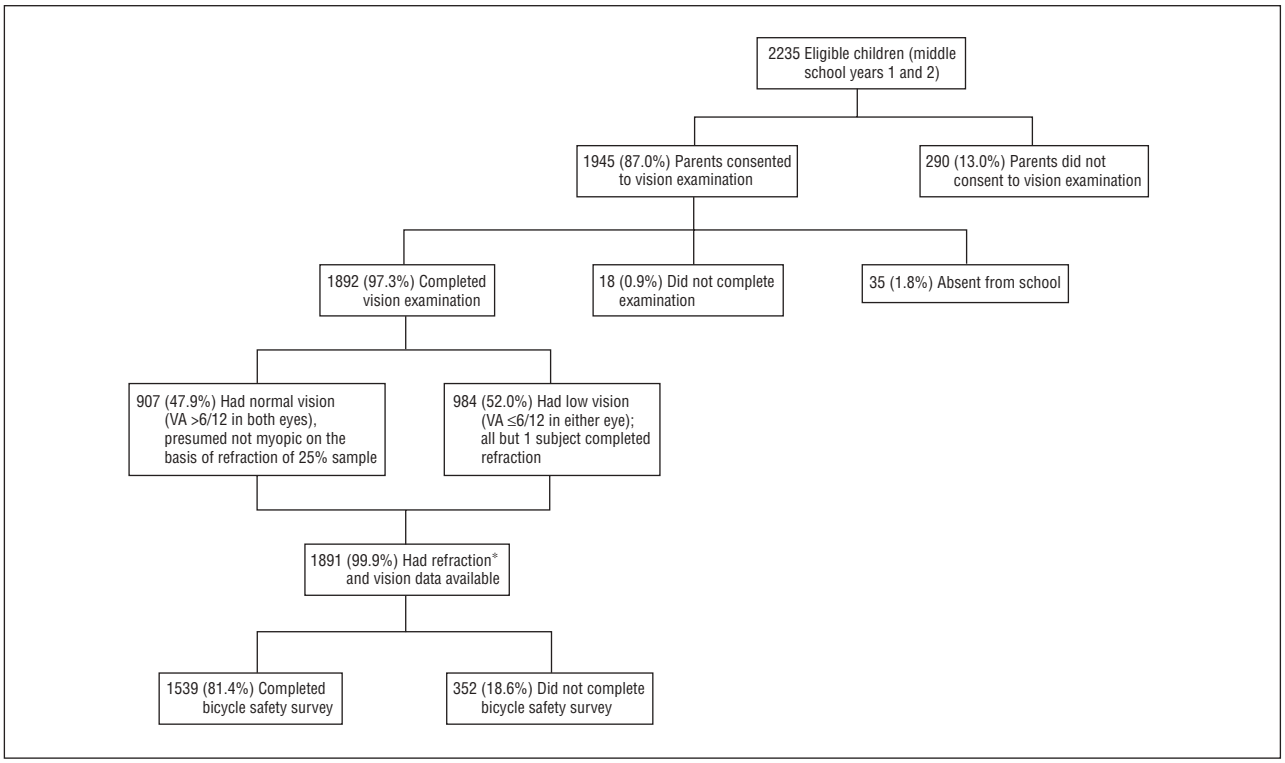

Figure. Flowchart detailing the recruitment and examination of participants for the Xichang Pediatric Refractive Error Study. Percentages have been rounded and may not total 100. *A random 25% sample of children with bilateral normal vision (n=248) underwent refraction, and none were found to have myopia of less than –4.0 diopters bilaterally, the cutoff used to define myopia in this study. Based on this finding, all children with normal vision were presumed to be nonmyopic in subsequent analyses. VA indicates visual acuity.

evaluation of refractive error prevalence and attitudes toward and uptake of refractive services among 1892 children in junior middle school years 1 and 2 (ages 13-17 years) in rural China. Because of compulsory education in this age range, the sample is likely representative of the local population. This report provides data on the prevalence of self-reported bicycle injuries during the past 3 years among the X-PRES cohort and on the association of visual impairment, myopia, and spectacle wear with bicycle injury risk, when adjusting for self-reported measures of riding exposure and risky riding behaviors.

METHODS

Xichang is a rural town with a population of 109 673 in 2002[12] that is located within 2 hours of the city of Shantou in eastern Guangdong province. Eye services are provided through a facility run cooperatively by the local government medical clinic and the Caring is Hip eye care program, supported by the Li Kai Shing Foundation (Hong Kong). Basic refractive services and spectacles are available at the eye clinic and also at a small number of privately run optical shops in Xichang and the surrounding area. Xichang includes more heavily settled, high-traffic areas and sections with lower traffic density. Traffic components include private cars, motorcycles, mopeds, commercial and farm vehicles, bicycles, and pedestrians; there are no provisions for separate bicycle lanes or paths in any part of the town.

A school-based survey was performed from April 1 through June 30, 2007, on a cluster-based random sample of children in junior middle school years 1 and 2 at all 3 middle schools in Xichang. The sample is likely representative of the population in this age range because of compulsory education in China to 16 years of age. The purpose of the survey was to determine the prevalence and predictors of visual disability, refractive error, and spectacle wear among Chinese rural-dwelling children and to assess the impact of visual disability on safety and daily activities. The protocol was approved by the Ethics Committee at the Joint Shantou International Eye Center in Shantou, parent hospital for the Xichang Eye Clinic. Informed consent was obtained from the parents of all participating children, and the tenets of the Declaration of Helsinki were followed throughout.

PARTICIPANTS

The parents of all eligible children were sent invitation letters explaining the purpose and methods of the study and were asked to return a form indicating whether they were willing for their child to participate. Among 2235 children in the sample, 2197 forms (98.3%) were returned, permission was granted for 1945 children (87.0% of the sample), and 1892 (84.7% of the sample) were examined (**Figure**).

ASSESSMENT OF VISION

The assessment of vision has been described elsewhere in detail.[2] Briefly, uncorrected visual acuity and visual acuity while wearing habitual refraction (if available) were measured in well-lighted areas during daylight hours, at a distance of 6 m, separately for each eye of each child by study personnel. Children who did not have their spectacles at school were asked to bring them for vision assessment on a separate day. Identical illuminated Snellen tumbling E vision

charts (Shantou City Medical Equipment Ltd, Shantou, China) were used for all testing.

QUESTIONNAIRES

All study participants (n=1891) (Figure) were administered a basic questionnaire by study personnel before being told the results of their vision assessment. The basic questionnaire included questions on age, sex, parental education, history of glasses wear, and reasons for nonwear of glasses.

The basic questionnaire also included a Chinese translation of an instrument developed originally by Fletcher et al[13] to assess self-reported visual function in rural Asia. All questions were administered in Mandarin or the local dialect (Chaoshanhua) by 1 of 6 native speakers after a period of training and standardization. The instrument was scored from 0 (worst) to 100 (best) and has been described elsewhere in detail.[14]

Three months later, children participating in the original survey were administered a questionnaire asking them to report the average number of days, hours, kilometers, and trips per week they completed while riding a bicycle. Children were asked about their participation in the following 8 risky riding behaviors: riding in the rain, riding after dark, not stopping for stop signs and/or red lights, riding on the sidewalk, riding against traffic, riding with 1 hand or no hands, riding with another child on the bicycle, and riding without a helmet. A score of 1 point was given for never engaging in the activity, 2 for occasionally, and 3 for frequently. Questions with yes or no answers were scored with the more dangerous behavior (no to wearing a helmet or yes to riding in the dark) receiving a score of 3 points and the safer behavior 1 point. Preferred side of the road for riding was scored from 1 to 6, with the highest (worst) score for always being on the left (incorrect) side. Total scores ranged from 8 (least dangerous) to 27 (most dangerous). Finally, children were asked to describe the number, severity, and characteristics of any bicycle accidents in which they had been involved in the past 3 years. Children's reports of bicycle activity and accidents were elicited retrospectively on a single occasion and were not based on diaries or subsequent contact by telephone or other means.

Although children were asked about their habitual patterns of glasses wear, the wear of spectacles for the purposes of our analyses was defined as having been observed to wear spectacles at the time of examination.

DETAILED EXAMINATION AND REFRACTION

A detailed examination and refraction were attempted for all participants with uncorrected visual acuity of 6/12 or worse in either eye (n=985 attempted refraction and n=984 completed refraction), and a 25% random sample of participants with visual acuity of better than 6/12 in both eyes (n=248 attempted and completed refraction) (Figure). This consisted of cycloplegia, achieved with 2 drops in each eye of cyclopentolate hydrochloride, 1%, administered 5 minutes apart, followed no less than 30 minutes later by autorefraction using a commercially available refractometer/keratometer device (Canon RK-F1; Canon, Inc, Tochigi, Japan). Autorefraction was refined with subjective refraction by an ophthalmologist separately in each eye. An ophthalmologist also performed a slitlamp examination (YZ5F1 slitlamp; Suzhou Liuliu, Suzhou, China) of the anterior and posterior segment in both eyes after dilation of the pupil.

STATISTICAL METHODS

Raw data are given as mean (SD) or as frequency and percentage where appropriate. Except for a 25% random sample, children with normal vision did not undergo refraction. In attributing myopia status to children with normal vision who did not undergo refraction, we assumed that they were not myopic. This assumption appears to be justified with regard to the cutoffs of less than −2.0 diopters (D), less than −3.0 D, and less than −4.0 D in both eyes used to define myopia in this study. Among 248 children with normal vision who were selected at random for refraction, only 2 (0.8%) had myopia of less than −2.0 D in both eyes, and none had myopia of less than −3.0 D or −4.0 D. Separate analyses were also performed that included only the 927 children who underwent refraction (all participants with visual acuity ≤6/12 and the 25% sample of those with normal vision).

All univariate comparisons were made using the *t* test, the Pearson χ^2 test, or the Fisher exact test, as appropriate. Logistic regression was used to assess potential factors associated with reporting having experienced at least 1 bicycle accident in the past 3 years. According to the study hypothesis, habitual visual acuity and refractive error were included in the model irrespective of significance in the univariate model, as were indices of exposure to bicycle riding and risky riding behavior because it was believed to be important to adjust for these potential confounders. Finally, age, sex, and any factors with $P \leq .3$ in the univariate analysis were also included. All statistical analyses were performed using commercially available software (SPSS 14.0; SPSS Inc, Chicago, Illinois). All statistical tests were 2-sided, and $P < .05$ was considered statistically significant.

RESULTS

Among 1892 children participating in the X-PRES, information on vision and self-reported frequency of bicycle riding, risky riding behaviors, and accidents was available for 1539 participants (81.3%) (Figure). These 1539 children form the basis for remaining analyses, except where otherwise specifically indicated. Children completing the bicycle survey had a mean age of 14.6 years, 52.5% were girls, 26.8% wore glasses, 4.2% had a habitual visual acuity worse than 6/18 in the better-seeing eye, and 12.9% had a spherical equivalent refractive error of less than −4 D in both eyes (**Table 1**). Children completing the survey were significantly younger, more likely to be female, and had more myopia than nonresponders (Table 1).

The rural Chinese secondary schoolchildren participating in the X-PRES used bicycles as their primary means of transportation. Overall, 91.6% relied on bicycles to get to school daily, and 41.1% made at least 25 trips per week by bicycle (**Table 2**). A total of 1529 children (99.4%) reported ever having ridden a bicycle in the past 3 years; this group formed the basis for the remaining analyses of vision and bicycle safety (Table 2).

Participants were asked about a number of behaviors potentially associated with increased risk of bicycle accidents or bicycle-related injuries (**Table 3**). Of these children, 2.8% wore helmets while riding, 57.6% rode after dark, and behaviors such as failing to stop at traffic lights, riding on the sidewalk or on the wrong side of the road, riding with 1 or no hands, and carrying passengers on the bicycle were common (Table 3). A summary risk score was calculated by assigning higher point values to more risky behaviors, with a mean (SD) value of 16.6 (1.9) (range, 8-27).

Table 1. Comparison by Sex of Children Who Did and Did Not Participate in a Survey of Bicycle-Related Injury History and Bicycle-Riding Behaviors in a Population of 1892 Rural Chinese Secondary Schoolchildren[a]

Characteristics	All (N=1892)	Sex Comparison Within Full Sample (N=1892)			Comparison Between Those Completing and Failing to Complete Survey			Sex Comparison Among Those Completing Survey (n=1539)		
		Boys (n=923)	Girls (n=969)	*P* Value	Did Not Complete (n=353)	Completed (n=1539)	*P* Value	Boys (n=731)	Girls (n=808)	*P* Value
Age, mean (SD), y	14.7 (0.8)	14.7 (0.8)	14.6 (0.8)	.08	14.8 (0.9)	14.6 (0.8)	<.001	14.7 (0.8)	14.6 (0.8)	.046
Sex										
Male	923 (48.8)				192 (54.4)	731 (47.5)	.02			
Female	969 (51.2)				161 (45.6)	808 (52.5)				
Wearing glasses										
No	1392 (73.6)	747 (80.9)	645 (66.6)	<.001	266 (75.4)	1126 (73.2)	.40	585 (80.0)	541 (67.0)	<.001
Yes	500 (26.4)	176 (19.1)	324 (33.4)		87 (24.6)	413 (26.8)		146 (20.0)	267 (33.0)	
Parents' highest education										
≤Primary school	413 (21.8)	193 (20.9)	220 (22.7)	.80	68 (19.3)	345 (22.4)	.49	155 (21.2)	190 (23.5)	.69
Junior middle school	880 (46.5)	436 (47.2)	444 (45.8)		168 (47.6)	712 (46.3)		348 (47.6)	364 (45.0)	
High school	576 (30.4)	282 (30.6)	294 (30.3)		111 (31.4)	465 (30.2)		220 (30.1)	245 (30.3)	
≥College	23 (1.2)	12 (1.3)	11 (1.1)		6 (1.7)	17 (1.1)		8 (1.1)	9 (1.1)	
Habitual visual acuity worse than 6/18 in better-seeing eye	75 (4.0)	35 (3.8)	40 (4.1)	.71	11 (3.1)	64 (4.2)	.37	30 (4.1)	34 (4.2)	.92
Spherical equivalent worse than –4 D in both eyes	230 (12.2)	82 (8.9)	148 (15.3)	<.001	32 (9.1)	198 (12.9)	.048	72 (9.8)	126 (15.6)	.001
Visual function score, mean (SD)	75.8 (16.3)	77.2 (16.0)	74.4 (16.5)	<.001	77.2 (15.5)	75.4 (16.5)	.07	76.7 (16.4)	74.3 (16.4)	.004

Abbreviation: D, diopters.
[a]Unless otherwise indicated, data are expressed as number (percentage) of patients. Because of rounding, percentages may not total 100.

Children were also requested to give information about bicycle accidents of various types in which they had been involved in the past 3 years (**Table 4**). A total of 2931 accidents were reported by 423 children, indicating that nearly one-third of them had had at least 1 accident. The total annual reported accident rate was 696 (95% confidence interval [CI], 682-710) per 1000 person-years. Serious accidents were not uncommon; 68 accidents requiring medical attention and 15 requiring inpatient treatment were reported (Table 4).

In logistic regression modeling of factors potentially associated with having reported at least 1 accident in the past 3 years, male sex (odds ratio [OR], 1.55; 95% CI, 1.22-1.96; $P<.001$) and glasses wear (OR, 1.38; 95% CI, 1.02-1.86; $P=.04$) were associated with significantly greater odds of accidents when adjusting for age, time spent riding, and the bicycle risk score (**Table 5**). However, habitual visual acuity of worse than 6/18 in the better eye and spherical equivalent of less than –4 D in both eyes were not associated with bicycle accidents in this model. These results were unchanged when a visual acuity cutoff of no better than 6/12 and refractive cutoffs of less than –2.0 D and less than –3.0 D were examined. Specifically, in an analysis including only those 927 children who underwent refraction (all participants with visual acuity ≤6/12 in either eye and a random 25% sample of those with normal vision) and completed the visual examination and bicycle survey (no missing responses), male sex (OR, 1.57; 95% CI, 1.17-2.11; $P=.003$) and wearing glasses at the time of the examination (OR, 1.70; 95% CI, 1.18-2.45; $P=.005$) were significantly associated with accident risk in the multivariate model, whereas habitual visual acuity of worse than 6/18 in the better eye ($P=.13$) and myopia of less than –2 D ($P=.09$) were not. Spectacle wear and male sex remained the only significant associations with accidents in models in which visual acuity and refraction were included separately or together as continuous variables, and in which the total number of accidents or of accidents requiring medical attention was used as the outcome. Only spectacle wear remained significantly associated in models including only boys (data not shown).

COMMENT

Although both bicycle accidents and myopia are common in this rural Chinese population, we failed to find any significant association between crash risk and refractive error or habitual visual acuity. There is a significant burden of myopia and poor vision in this population,[1,2] which has been associated in this[1] and other[3] groups with poor self-reported visual function. Given the significant resources that would be needed to ameliorate this problem, we believe that even a negative finding in this context is of interest, and we hope this report will stimulate further studies of the impact of refractive error on activities of daily living among children.

Few other reports have examined the question of whether visual disability is a risk factor for injury in children. A German report concluded that visual impairment significantly increased the risk of injuries of all types examined at a hospital,[6] but the assessment of vision appears to have been based on self-report. To the best of our knowledge, ours is the first study to examine the association between objectively measured visual acuity and refractive error and a history of accidents during childhood in this setting.

The literature on visual disability and motor vehicle crashes among elderly persons has been comparatively plentiful. Visual field loss,[15] cataracts,[16] and glau-

Table 2. Distribution of Self-reported Bicycle Exposure Characteristics Among 1539 Rural Chinese Secondary Schoolchildren

Characteristic	No. (%) of Participants[a]
Ever ridden bicycle in past 3 years	
No	10 (0.6)
Yes	1529 (99.4)
Most common type of transportation used to get to school	
Walking	107 (7.1)
Riding a bicycle	1382 (91.6)
Other	19 (1.3)
Failed to respond	31
Average No. of days riding per week	
<1	51 (3.4)
1-2	24 (1.6)
3-4	35 (2.3)
5-7	1392 (92.7)
Failed to respond	37
Average No. of bicycle trips per week	
≤5	244 (16.5)
6-9	114 (7.7)
10-19	125 (8.5)
20-24	387 (26.2)
≥25	606 (41.1)
Failed to respond	63
Average distance ridden per week, km	
<5	461 (32.8)
5-19	296 (21.1)
20-49	269 (19.1)
50-99	153 (10.9)
100-150	107 (7.6)
>150	119 (8.5)
Failed to respond	134
Average time spent riding per week, h	
<1	225 (15.4)
1-2	282 (19.3)
3-4	275 (18.8)
5-9	332 (22.7)
10-15	149 (10.2)
>15	198 (13.6)
Failed to respond	78

[a] Percentages are based on the number of participants who responded to each question.

Table 3. Distribution of Self-reported Risky Bicycle-Riding Behaviors Among 1529 Rural Chinese Children Who Reported Riding in the Past 3 Years[a]

Characteristic	No. (%) of Participants[b]
Usually wear helmet while riding	
No	1445 (97.2)
Yes	42 (2.8)
Failed to respond	42
Ride bicycle in rain	
No	1042 (70.2)
Yes	442 (29.8)
Failed to respond	45
Ride bicycle when dark outside	
No	635 (42.4)
Yes	862 (57.6)
Failed to respond	32
Stop at stop signs and traffic lights	
Often	824 (55.6)
Sometimes	424 (28.6)
Never	234 (15.8)
Failed to respond	47
Ride on sidewalk	
Never	697 (47.1)
Sometimes	529 (35.7)
Often	255 (17.2)
Failed to respond	48
Side of road used (right side is correct)	
Always on right	745 (51.1)
More often on right	452 (31.0)
More often on left	216 (14.8)
Always on left	44 (3.0)
Failed to respond	72
Ride with ≥1 hands off handlebars or holding other objects	
Never	249 (16.7)
Sometimes	1127 (75.4)
Often	118 (7.9)
Failed to respond	35
Ride with >1 person on bicycle	
Never	294 (19.6)
Sometimes	1138 (76.0)
Often	66 (4.4)
Failed to respond	31

[a] The mean (SD) total risk score of the risk factors was 16.6 (1.9) (minimum, 8; maximum, 27). A higher score indicates more risky behavior.
[b] Percentages are based on the number of participants who responded to each question. Because of rounding, percentages may not total 100.

coma[17] have been associated with increased incidence of automobile crashes. Visual acuity, however, has at most been weakly correlated with increased risk of accidents,[18-21] and often no significant association has been observed.[22-25] This is in keeping with the findings of our study.

It has been postulated that the lack of above-normal injury levels among visually impaired adults while driving may be a result of driving less,[26,27] taking fewer risks, driving more slowly, and driving only during the daytime or in familiar surroundings.[18,28-30] We reviewed our own data for comparable trends but found that weekly riding time and distance did not differ significantly between participants with habitual visual acuity in the better eye that was better or worse than 6/18 (data not shown). Among the risky riding behaviors about which we inquired in our survey, only failure to stop at red lights or stop signs was significantly less common among children with poor vision (8.1% of visually impaired children vs 16.1% of those with better vision reported seldom stopping at marked intersections; $P=.02$ adjusting for age and sex). It should be remembered that the various indices of riding exposure and risky riding behavior were not associated with injury outcome in the study's data set.

Although we failed to observe any association between myopia or habitual visual acuity and bicycle accidents, children wearing spectacles were at significantly increased risk of crashes. Although the magnitude of the unadjusted difference was modest, in various models adjusting for age, sex, riding exposure, visual acuity, refraction, and risky behaviors, the increased odds of a crash was 35% to 70% among children who were wearing glasses at the time of their

study examination. Our hypothesis is that spectacle wear may lead to a decrement in the peripheral visual field, thus reducing rider awareness of oncoming vehicles and road obstacles. In this context, our results are consistent with reports of increased risk of automobile crashes among drivers with peripheral visual fields impaired by other causes.[15] The Salisbury Eye Evaluation, for example, followed up 1801 drivers aged 65 to 84 years during a period of 3 to 5 years and examined the association between automobile crash involvement and a number of visual indices, including acuity, contrast sensitivity, stereoacuity, and visual field.[28] Among these, only visual field was significantly associated with involvement in an accident. Peripheral scotomata associated with spectacle wear and potentially relevant to motor vehicle driving safety have been reported.[31]

Table 4. Distribution of Self-reported Bicycle Accident Experience Among 1529 Rural Chinese Children Who Reported Riding in the Past 3 Years

Characteristic	Participants Reporting[a]
No. of bicycle accidents in past 3 y	
0	1106 (72.3)
1-2	105 (6.9)
3-4	105 (6.9)
5-8	107 (7.0)
>9	106 (6.9)
Frequency of accidents of various types	
With car	27 (1.8)
With bicycle/motorcycle	272 (17.8)
With pedestrian	207 (13.5)
With stationary object or car door	181 (11.8)
Due to poor road conditions	218 (14.3)
Due to failure to control bicycle	291 (19.0)
Total No. of reported bicycle accidents in past 3 y	2931
Accidents requiring medical attention	68 (4.4)
Accidents requiring in-patient hospital care	15 (9.8)
Duration of hospital stay, median (IQR), d	2 (2-4)
Accidents requiring student to miss school	23 (1.5)
Duration of missing school, median (IQR), d	2 (1-4)

Abbreviation: IQR, interquartile range.
[a]Unless otherwise indicated, data are expressed as number (percentage) of patients who completed the bicycle survey.

Given the high incidence of myopia[2] and bicycle accidents in this population, it may be prudent to consider education at the time of dispensing glasses, emphasizing careful scanning of the road while bicycling and wearing spectacles to reduce the risk of accidents. There are, however, potential concerns about negative social marketing associated with such strategies, given the already low levels of use of glasses among those with significant myopia in rural China.[1,2]

Our finding of 50% increased odds of bicycle accidents among boys is generally consistent with the trauma literature, which reports increased risk of most injuries among males compared with females, particularly at younger ages.[32] This association persisted after adjustment for bicycling exposure and self-reported risky cycling behaviors, suggesting that these factors failed to fully explain the excess risk among boys or that our metrics did not fully describe them. The possibility that boys were more forthcoming than girls in reporting their accidents cannot be excluded.

This report from the X-PRES must be understood within the context of its limitations. First, all indices of bicycle-riding exposure, risky behaviors, and accident outcomes were self-reported, leaving open the possibility of bias and inaccuracy. No standard definition of a bicycle injury was provided, which likely led to the inclusion of a large number of rather modest events among our data. The lack of an association persisted when only crashes requiring medical attention were considered. Still, our failure to observe an association between accidents and refraction or vision may to some extent be a reflection of our methods and thus requires confirmation by other investigators.

Visual acuity in this study was measured with a Snellen chart, although logMAR charts have been suggested to offer superior test-retest variability and to discriminate more accurately between persons with and without visual disability.[33] Our reason for making this choice is that refraction using logMAR charts may be "notoriously time-consuming and frustrating."[33] Although the use of Snellen charts in this study of refractive error was logistically practical, the possibility must be acknowledged that resulting decreased accuracy in vision measurements may have contributed to our failure to detect an association be-

Table 5. Logistic Regression Model for Association Between Bicycle Accidents and Potential Predictors Among 1403 Rural Chinese Secondary Schoolchildren With Completed Bicycle Surveys (No Missing Responses) and Vision Examination[a]

	Reported ≥1 Accident in Past 3 y					
Independent Variable	No (n=980)	Yes (n=423)	Univariate OR	*P* Value	Multivariate OR (95% CI)	*P* Value
Age, mean (SD), y	14.7 (0.8)	14.6 (0.8)	0.93	.30	0.90 (0.78-1.05)	.17
Male sex	426 (43.5)	227 (53.7)	1.51	<.001	1.55 (1.22-1.96)	<.001
Wearing glasses at time of examination	260 (26.5)	124 (29.3)	1.15	.28	1.38 (1.02-1.86)	.04
Baseline visual acuity worse than 6/18 in better-seeing eye	40 (4.1)	20 (4.7)	1.17	.58	1.29 (0.72-2.32)	.39
Spherical equivalent worse than –4 D in both eyes	134 (13.7)	55 (13.0)	0.94	.73	0.80 (0.54-1.18)	.26
Bicycle-riding risk score, mean (SD)	16.6 (1.9)	16.7 (1.9)	1.03	.28	1.04 (0.98-1.10)	.24
Reported riding ≥10 h/wk	217 (22.1)	107 (25.3)	1.18	.22	1.16 (0.89-1.53)	.27

Abbreviations: CI, confidence interval; D, diopter; OR, odds ratio.
[a]Unless otherwise indicated, data are expressed as number (percentage) of patients who completed the bicycle survey and underwent the vision examination.

tween vision and bicycle accidents. It seems unlikely that a strong association would have been missed for this reason, however.

Only 25% of participants with normal vision in this sample underwent actual refraction. Thus, it is possible that misclassification may have occurred, with the children who did not undergo refraction having normal vision and undetected myopia being incorrectly treated as nonmyopic in our analyses. However, among 248 children with normal vision who underwent refraction, we identified none with a spherical equivalent refractive error of less than –3.0 or –4.0 D in both eyes and only 2 (0.8%) with less than –2.0 D in both eyes. It is still possible that our having classified children with lesser degrees of myopia as nonmyopic may have attenuated an existing association between myopia and bicycle crashes. However, in analyses including only those who actually underwent refraction, refractive error (treated continuously) was still unassociated with bicycle crashes (data not shown).

Spectacle wear in this study was assessed according to students' observed wear at the time of examination. We chose this approach in preference to ascribing glasses wear to children on the basis of their own self-report because we believed that direct observation was more reliable. When separate analyses were performed attributing glasses wear only to children who indicated that they usually wore glasses, the association with crashes and glasses wear remained unchanged (data not shown). Nonetheless, the possibility exists that misclassification may have occurred and that not all children identified as wearing glasses were truly using spectacles regularly while riding their bicycles. Participants were asked to give a history of bicycle accidents during the past 3 years. It is also possible that not all children wearing spectacles at the time of the examination were doing so during the past 3 years. However, the mean refractive error of children observed wearing spectacles was –3.55 (1.47) D. It seems unlikely that children with this degree of refractive error became myopic only within the past 3 years. Misclassification with regard to spectacle wear would generally have been expected to attenuate rather than strengthen the observed association between glasses use and bicycle accidents. The possibility also cannot be excluded that the spectacles children were wearing during the 3-year period were inaccurate because such inaccuracies are common in this population[34]; wearing incorrect spectacles may have contributed in part to the association between glasses wear and accidents.

Finally, only 81.4% of study participants completed the bicycle survey, and statistically significant differences (although small in magnitude) existed between respondents and nonrespondents. Therefore, one should be cautious about applying these results to the general population of schoolchildren in this area or elsewhere in rural China.

Nonetheless, this report provides unique data on the impact of visual impairment, refractive error, and spectacle wear on the daily activities of a large population with a very high burden of myopia, that is, children in rural China. Given the unusually high prevalence of visual disability in this group, further studies assessing its effect on activities of daily living will be important for program planners and policy makers.

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REFERENCES

1. He M, Huang W, Zheng Y, Huang L, Ellwein LB. Refractive error and visual impairment in school children in rural southern China. *Ophthalmology*. 2007; 114(2):374-382.
2. Congdon N, Wang Y, Song Y, et al. Visual disability, visual function and myopia among rural Chinese secondary school children: the Xichang Pediatric Refractive Error Study (X-PRES) report 1. *Invest Ophthalmol Vis Sci*. 2008;49(7): 2888-2894.
3. Esteso P, Castanon A, Toledo S, et al. Correction of moderate myopia is associated with improvement in self-reported visual functioning among Mexican school-aged children. *Invest Ophthalmol Vis Sci*. 2007;48(11):4949-4954.
4. National Center for Injury Prevention and Control. *CDC Injury Fact Book*. Atlanta, GA: Centers for Disease Control and Prevention; 2006:2.
5. World Health Organization. Accidents in children and young people. *World Health Stat Q*. 1986;39(3):216-221.
6. Schneiders W, Rollow A, Rammelt S, et al. Risk-inducing activities leading to injuries in a child and adolescent population of Germany. *J Trauma*. 2007;62 (4):996-1003.
7. Haileyesus T, Annest JL, Dellinger AM. Cyclists injured while sharing the road with motor vehicles. *Inj Prev*. 2007;13(3):202-206.
8. Berg P, Westerling R. A decrease in both mild and severe bicycle-related head injuries in helmet wearing ages: trend analyses in Sweden. *Health Promot Int*. 2007;22(3):191-197.
9. Shah S, Sinclair SA, Smith GA, Xiang H. Pediatric hospitalizations for bicycle-related injuries. *Inj Prev*. 2007;13(5):316-321.
10. Li G, Baker SP. Injuries to bicyclists in Wuhan, People's Republic of China. *Am J Public Health*. 1997;87(6):1049-1052.
11. Wang CC, Schoenberg BS, Li SC, Yang YC, Cheng XM, Bolis CL. Brain injury due to head trauma: epidemiology in urban areas of the People's Republic of China. *Arch Neurol*. 1986;43(6):570-572.
12. Information on Jiedong (in Chinese). http://www.jiedong.gd.cn/mxqz/xcz.htm. Accessed August 7, 2007.
13. Fletcher AE, Ellwein LB, Selvaraj S, Vijaykumar V, Rahmathullah R, Thulasiraj RD. Measurements of vision function and quality of life in patients with cataracts in southern India. *Arch Ophthalmol*. 1997;115(6):767-774.
14. He M, Xu J, Li S, Wu K, Munoz SR, Ellwein LB. Visual acuity and quality of life in patients with cataract in Doumen County, China. *Ophthalmology*. 1999;106 (8):1609-1615.
15. Ball K, Owsley C, Sloane ME, Roenker DL, Bruni JR. Visual attention problems as a predictor of vehicle crashes in older drivers. *Invest Ophthalmol Vis Sci*. 1993; 34(11):3110-3123.
16. Owsley C, McGwin JG Jr, Ball K. Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly. *Ophthalmic Epidemiol*. 1998;5(2):101-113.
17. Owsley C, McGwin JG Jr. Vision impairment and driving. *Surv Ophthalmol*. 1999; 43(6):535-550.
18. Hills BL, Burg A. *A Reanalysis of California Driver Vision Data: General Findings: Report LR 768*. Crowthorne, England: Transport and Road Research Laboratories; 1977.
19. Hofstetter HW. Visual acuity and highway accidents. *J Am Optom Assoc*. 1976; 47(7):887-893.
20. Humphriss D. Three South African studies on the relation between road accidents and drivers' vision. *Ophthalmic Physiol Opt*. 1987;7(1):73-79.
21. Marottoli RA, Richardson ED, Stowe MH, et al. Development of a test battery to identify older drivers at risk for self-reported adverse driving events. *J Am Geriatr Soc*. 1998;46(5):562-568.
22. Gresset JA, Meyer FM. Risk of accidents among elderly car drivers with visual acuity equal to 6/12 or 6/15 and lack of binocular vision. *Ophthalmic Physiol Opt*. 1994;14(1):33-37.

23. Ivers RQ, Mitchell P, Cumming RG. Sensory impairment and driving: the Blue Mountains Eye Study. *Am J Public Health*. 1999;89(1):85-87.
24. Johansson K, Bronge L, Lundberg C, Persson A, Seideman M, Viitanen M. Can a physician recognize an older driver with an increased crash risk potential? *J Am Geriatr Soc*. 1996;44(10):1198-1204.
25. McCloskey LW, Koepsell TD, Wolf ME, Buchner DM. Motor vehicle collision injuries and sensory impairments of older drivers. *Age Ageing*. 1994;23(4):267-273.
26. Freeman EE, Munoz B, Turano KA, West SK. Measures of visual function and time to driving cessation in older adults. *Optom Vis Sci*. 2005;82(8):765-773.
27. Keeffe JE, Jin CF, Weih LM, McCarty CA, Taylor HR. Vision impairment and older drivers: who's driving? *Br J Ophthalmol*. 2002;86(10):1118-1121.
28. Rubin GS, Ng ESW, Bandeen-Roche K, Keyl PM, Freeman EE, West SK; SEE Project Team. A prospective, population-based study of the role of visual impairment in motor vehicle crashes among older drivers: the SEE Study. *Invest Ophthalmol Vis Sci*. 2007;48(4):1483-1491.
29. Legood R, Scuffham P, Cryer C. Are we blind to injuries in the visually impaired? a review of the literature. *Inj Prev*. 2002;8(2):155-160.
30. Stutts JC, Stewart JR, Martell C. Cognitive test performance and crash risk in an older driver population. *Accid Anal Prev*. 1998;30(3):337-346.
31. Steel SE, Mackie SW, Walsh G. Visual field defects due to spectacle frames: their prediction and relationship to UK driving standards. *Ophthalmic Physiol Opt*. 1996;16(2):95-100.
32. Congdon N, Schein OD. The epidemiology of ocular trauma . In: MacCumber MW, ed *Management of Ocular Emergencies*. Philadelphia, PA: Lippincott-Raven; 1997:9-28.
33. Hussain B, Saleh GM, Sivaprasad S, Hammond CJ. Changing from Snellen to LogMAR: debate or delay. *Clin Experiment Ophthalmol*. 2006;34(1):6-8.
34. Zhang MZ, Lv H, Gao Y, et al. Visual morbidity due to inaccurate spectacles among school-children in rural China: the See Well to Learn Well Project, report 1 [published online January 10, 2009]. *Invest Ophthalmol Vis Sci*. doi:10.1167/iovs.08-2849.