Using incognito standardised patients to evaluate quality of eye care in China

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ABSTRACT

Background/aims Few studies have objectively examined the quality of eye care in China. We assessed refractive care using the incognito standardised patient (SP) approach, a gold standard for evaluating clinical practice.

Methods A total of 52 SPs were trained to provide standardised responses during eye examinations, and underwent automated and non-cycloplegic, subjective refraction by a senior ophthalmologist from Zhongshan Ophthalmologic Center, a national-level clinical and research centre. SPs subsequently received subjective refraction and eye exams at a randomly selected sample of 40 public hospitals and 93 private optical shops in Shaanxi, Northwestern China. Difference between expert and local refraction in the better-seeing eye was calculated by the vector diopteric method, and completeness of exams assessed against national standards. SP and provider demographic information and provider clinical experience were recorded.

Results SPs (n=52, mean (range) age, 25.7 (22–31) years, 28.8% male) underwent 133 eye exams (mean total duration 15.0±11.7 min) by 133 local refractionists (24–60 years, 30.3% male). Only 93 (69.9%), 121 (91.0%) and 104 (78.2%) of local refractionists assessed vision, automated and subjective refraction, respectively. The median inaccuracy was −0.25 diopters (D), while 25.6% of results differed by an absolute value of ≥1.0 D and 6.0% by ≥2.0 D. Predictors of inaccurate refraction included spectacle power <−6.0 D (OR=2.66; 95% CI, 1.27 to 5.56), service at a public (vs private) hospital (OR=2.01; 95% CI, 1.11 to 3.63) and provider male sex (OR=2.03; 95% CI, 1.11 to 3.69).

Conclusion Inaccurate refractions are common in Northwestern China, particularly in public facilities. Important assessments, including subjective refraction, are frequently omitted.

INTRODUCTION

Over one-quarter of the world's estimated 285 million visually impaired individuals live in China, and uncorrected refractive error is the leading cause of visual impairment in the world.[1–3] Although glasses provide a safe and inexpensive way to treat refractive error, usage in China is low.[4] In rural areas, only 17% of rural children who need glasses actually own them.[5]

While cost, lack of knowledge and common misunderstandings regarding safety of glasses and effective means to prevent myopia are important barriers to receiving refractive care,[6 7] recent studies suggest that the provision of inaccurate glasses may add to the associated burden of visual disability in many populations.[7–9] This is of particular concern in China, where recent studies have raised concerns about the country's poor quality of healthcare in both rural and urban areas, including a well-documented problem of over-provision of unnecessary services and drugs, and a low rate of correct diagnosis at the primary care level.[10 11]

Despite the potential negative effects of receiving poor quality eye care, few studies have examined this issue in China.[7 12] There is a need for research on this topic given the approaching deadline of the Global Vision 2020 initiative aiming to eliminate avoidable blindness and visual impairment in China by 2020.[13] In the few existing studies, researchers have discovered a high rate of inaccuracy in glass prescriptions. Nearly half of children in rural Guangdong with glasses (48.8%) had power inaccurate by ≥1 diopters (D), 17.7% by ≥2 D.[7] In half the cases where rural refractionists in Western China stated that children's vision could not be improved with glasses, more experienced practitioners could indeed do so.[12]

There are a number of limitations to previous studies. These have focused only on specific locations or populations in China,[14] based their assessment of inaccuracy on currently worn glasses (which may be outdated) and failed to mask expert refractionists to the results of the practitioners they were evaluating, potentially leading to bias.[12] Other studies have focused on prescription records and repeat refractions in a controlled setting and may not have represented actual practice.[12 15] Studies of healthcare outside of the ophthalmic field have clearly delineated the importance of assessing quality in a venue that most closely mimics the actual practice of medicine.[10 16 17] In short, any study that depends on direct observation or face to face interviews when the observer is not masked is in danger of producing biassed results, since providers may strive to deliver higher-quality care when they know that they are being observed or tested.[17]

To address these issues, the current study used incognito standardised patients (SPs), trained to portray, in a standardised way, regular patients in a clinical encounter. SPs seek to keep their identity anonymous so that their presence will not influence behaviour of the clinicians under observation. In recent years, SPs have been increasingly used in developing country settings to evaluate quality of care.[18] The SP approach has long been considered the gold standard for assessing clinical practice, and has recently been found especially suited

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to the assessment of optometric practice.[17] Unannounced SP visits allow refractionists' results to be compared against a gold-standard benchmark, providing a rare opportunity to measure quality of eye care objectively. Furthermore, because case presentations are standardised, the SP method allows for robust quality comparisons across different providers and optical facility types, controlling for case and patient mix.

The primary aim of the current study is to provide objective evidence on the quality of rural and urban optical care delivered by local providers in Northwestern China, based on interactions between eye care providers and incognito SPs. This study is the first of which we are aware to use SPs to assess eye care in China or any developing country.

MATERIALS AND METHODS

Sampling procedures

Our study was conducted in Shaanxi province, representing a catchment area of 37 million individuals. Shaanxi is a northwestern province in China with large wealth disparities, as measured by the range of gross domestic product (GDP) per capita among its counties (US$4140–US$11 523).[19] In 2016, Shaanxi's GDP per capita of US$7609 was slightly below China's figure of US$8123.[20]

To assess the quality of eye care across Shaanxi province, we developed separate sampling procedures for Xi'an, the capital, and the remainder of the province, selecting both public hospitals with ophthalmology/optometry departments and private optical shops. The capital Xi'an was weighted more heavily due to the large proportion of optical chains having headquarters there. In Xi'an, we used Baidu Maps,[21] China's most widely used mapping application, to compile a list of public and private optical facilities first. Then one-fifth (n=54) of the eligible private optical shops (n=270) were randomly selected for our sample, as were all 26 public hospitals with ophthalmology departments, for a total of 80 facilities.

To choose our sample in the remainder of the province, we followed a three-step process. First, we created a list of all 94 counties and districts excluding Xi'an. Second, we randomly selected one-fifth of them (n=18), and then compiled a list of public and private optical facilities using Baidu Maps. Each of the selected counties and districts had an average of 10 private optical shops and one public hospitals with ophthalmology department. Third, in each of the selected counties and districts, two private optical shops (n=36) were randomly selected while all public hospitals with ophthalmology departments (n=17) were included for a total of 53 facilities, implying the same sampling proportion (one-fifth of the private facility and all of the public facilities) as we did in Xi'an. Therefore, the sampling proportion in Xi'an is five times as much as that in the remainder of the province. Sampled in this way, we yielded a total study sample of 133 facilities which was representative of the province.

The study was conducted in accordance with the principles of the Declaration of Helsinki and received ethical approval from the Stanford University Institutional Review Board (IRB, Protocol ID 36264). The IRB approved not having obtained informed consent from the local refractionists, as this would have eliminated the advantage of the incognito approach. The questionnaires, case scripts and checklists are available at https://pan.baidu.com/s/1fp20y9dh24to7uqphWo_cAhttps://pan.baidu.com/s/1fp20y9dh24to7uqphWo_cA.

SP screening and training

To ensure that the SPs were similar to patients typically seen by optical providers (in terms of fluency in local dialect, dress, etc), SPs were selected among graduate students at Shaanxi Normal University recruited from the local counties. One month prior to visits to local eye care facilities, all SPs underwent baseline non-cycloplegic eye examinations including an assessment of visual acuity as well as automated (repeated three times) and subjective refractions in each eye separately. SPs underwent automated refraction (Xinyuan FA-6100, Zhongbei Xinyuan, Taiyuan, China) without cycloplegia, with the best-corrected distance visual acuity and refractive power for each eye being output automatically. The mean automated value for three readings was computed automatically and used as the starting point for subjective refinement by an ophthalmologist from Zhongshan Ophthalmologic Center (ZOC), a top-ranking, national-level clinical and research centre.

After the baseline refraction, all SPs underwent 3 days of intensive training led by researchers at Shaanxi Normal University. All protocols and scripts used were developed by the research team in consultation with ophthalmologists from ZOC. During training, the SPs memorised scripts, learnt to role-play and rehearsed behaviours exhibited by real patients.

Facility visits and data collection

SPs visited sample optical providers in February 2016. In order to simulate actual conditions under which patients visit optical shops (usually due to some discrepancy between their ideal power and the glasses currently worn), all SPs were given a pair of glasses with power 0.50 D less than that of their actual prescription (ie, less minus or myopic power), which they brought to sample optical providers for assessment. SPs underwent examinations as offered and made no attempt to request specific providers. They were instructed to answer all questions during assessment of visual acuity, automated and subjective refraction according to their actual ability. If asked, SPs stated that they had been experiencing blurry vision for 1–2 weeks, with no headache or other accompanying symptoms. We wished to avoid use of cycloplegia, which is not permitted at private optical shops in China and not widely used on adults at public hospitals, and might thus have influenced our results as an uncontrolled variable. Thus, SPs were instructed in all cases to refuse cycloplegia during facility visits if offered (though all offers to use cycloplegia were recorded).

SPs completed a 'debriefing questionnaire' on exiting the facilities on the tests conducted, prescriptions received, examination fees and cost of any glasses suggested for purchase. Prescription and cost data were confirmed against written documents received during the visit. Where glasses were available for purchase (such sales are not permitted at all public clinics), they were tested for accuracy by automated lensometry (Jinglian 500B, ShanghaiJinglian, Shanghai, China) against the ZOC expert's prescription and that of the local refractionist.

Following SP visits, half of the facilities (n=66) were selected at random for more comprehensive surveys, including details on number of staff and facility size, demographic characteristics, educational attainment and salary of the refractionists who conducted SP examinations.

Quality measures

We evaluated optical providers on three dimensions of quality as observed from their interaction with the SPs: process quality, refraction accuracy and accuracy of dispensing. For process

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quality, tests completed were compared against a clinical checklist taken from the preferred practice patterns (PPP) of the American Academy of Ophthalmology (AAO),[22] which has been officially adopted in China. Accuracy of refraction and dispensing were evaluated using the vector dioptric difference (VDD) in the better-seeing eye between the ZOC expert's prescription on the one hand and both the local refractionist's prescription and measured power of glasses (if provided) on the other.

Statistical methods

The following formula[15 23] was used to calculate the vector difference in diopters, conventionally positive, between the final prescriptions of the local refractionist and the ZOC expert optometrist for each eye of each SP:

$$\text{Vector Dioptric Distance (VDD)} = \sqrt{2} \times \sqrt{\left[(SE_1 - SE_2)^2 + (J0_1 - J0_2)^2 + (J45_1 - J45_2)^2\right]}$$

where SE is the spherical equivalent refractive error (sphere +cylinder/2), J0=−(cylinder power/2) ×cos(2×axis), J45=−(cylinder power/2)× sin(2×axis).

To determine whether local refractionists tended to give more or less myopic prescriptions than ZOC optometrists, VDD was recorded as negative when the power prescribed by the local refractionist was more myopic than that called for by the ZOC optometrist.

Characteristics of SPs, facilities and local refractionists were assessed as potential determinants of inaccurate prescriptions, taking the ZOC optometrist as a gold standard. Logistic regression models were used to estimate ORs for different characteristics of the local refractionists and the facilities. The difference of ≥1.0 D (absolute value) in either eye between power prescribed by the local refractionist and the ZOC optometrist was taken as the cut-off for an inaccurate result. A random intercept model was used to adjust for the correlation between eyes of the same SP.[24] All analyses were performed using Stata V.14.0 (StataCorp LP, College Station, Texas, USA).

RESULTS

A total of 52 SPs (15 (28.8%) men; mean (range) age, 25.7 ([22–31) years) underwent 133 eye exams, one each in 40 public hospitals and 93 private optical shops (table 1). Based on the benchmark initial refraction at ZOC, 22 (42.3%) of the SPs had a spherical equivalent of >−3.0 D; 19 (36.5%) between −6.0 D and −3.0 D; and 11 (21.2%) <−6.0 D in the better-seeing eye. In total, 37 (71.2%) of the SPs could be corrected to 6/6 in both eyes, while all SPs could be corrected to 6/7.5 in at least one eye.

Providers (n=66 in the sample with demographic data, 20 (30.3%) men, mean (range) age, 38.0 (24–60) years) had a college education in 47 (71.2%) cases. The majority of providers had the second-highest (n=31, 47.7%) or highest (n=22, 33.9%) of five levels of refraction certification in China (table 1). The median annual salary of local refractionists was US$7164 (range, US$3220 to US$14 300). Among the 93 private optical shops, 69 (74.5%) were part of larger retail chains, while 22 (55.0%) of public facilities had glasses available for sale.

The mean duration of eye exams (including assessment of visual acuity, automated and subjective refraction in both eyes) was 15.0 min (table 2). Among items in the Preferred Practice Pattern of the American Academy of Ophthalmology (AAO PPP), 93 (69.9%) of local refractionists assessed visual acuity, 98 (73.7%) measured interpupillary distance, 121 (91.0%) performed automated refraction, 104 (78.2%) carried out subjective refraction and 80 (60.2%) measured the power of existing glasses. There were no significant differences in process quality between the local providers inside and outside of the provincial capital (table 2). Compared with public hospitals, private facilities were more likely to carry out automated refraction and measure the power of existing glasses, while they were less likely to assess visual acuity and offer cycloplegia. Only one of the private facilities referred a patient for further testing while 57.5% (n=23) of the public hospitals did (table 2).

Table 1 Basic characteristics of SPs and local refractionists

Variables	Mean (SD) or N (%)
SP characteristics (n=52)	
Age (years), mean (SD)	25.7 (2.01)
Male, n (%)	15 (28.9)
Spherical equivalent refractive power in the better-seeing eye, n (%)	
≥−3.0 D	22 (42.3)
<−3.0 D and >−6.0 D	19 (36.5)
≤−6.0 D	11 (21.2)
Facility characteristics (n=133)	
Public (vs private), n (%)	40 (30.1)
Located in Xi'an (provincial capital), n (%)	80 (60.2)
Characteristics of local refractionists (n=66)	
Male, n (%)	20 (30.3)
Age (years), n (%)	
≤30	17 (26.2)
31–40	27 (41.5)
>40	21 (32.3)
Education, n (%)	
High school	19 (28.8)
College	47 (71.2)
Certification, n (%)	
Middle	12 (18.5)
High	31 (47.7)
Senior	22 (33.9)
Annual salary, median (SD), US$	7164 (1940)

SPs, standardised patients.

The median difference between the final prescription power of local versus expert refractionists was −0.250 D (indicating a more myopic refractive power for the local refractionists), while 25.6% (n=34) of results differed by an absolute value of ≥1.0 D and 6.0% (n=8) by ≥2.0 D (table 2). Regarding the likelihood of offering inaccurate prescriptions, no significant difference was found between providers inside (20/80, 25.0%) versus outside (14/53, 26.4%, p=0.856) the provincial capital of Xi'an, or between public (20/93, 21.5%) and private (14/40, 35.0%, p=0.103) providers. Accuracy of the final prescription did not improve significantly when local refractionists conducted subjective refraction (24/104=23.1% inaccurate by ≥1.0 D) compared with when they did not (10/29=34.5%, p=0.213, figure 1).

In simple regression models, predictors of inaccurate refraction included spectacle power <−6.0 D (OR=2.66; 95% CI, 1.27 to 5.56; p=0.009), examination at a public hospital (OR=2.01; 95% CI, 1.11 to 3.63; p=0.021) and being seen by a male refractionist (OR=2.03; 95% CI, 1.11 to 3.69; p=0.021; table 3). These three characteristics remained significantly associated in multiple regression models, whether including all 133 facilities, or only the 66 where refractionist-level characteristics were collected. In this latter model, male SPs were at greater risk (OR=4.13; 95% CI, 1.19 to 14.3; p=0.025) of receiving inaccurate prescriptions. Provider education, certification and salary were not significantly associated with risk of inaccurate refraction.

Lens prescriptions of the purchased glasses were within 1.0 D of the expert refractionist benchmark in 75% of cases, and lenses

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Table 2 Process quality indicators, refraction inaccuracy and associated fees for refraction and eye exam by facility location and type

Characteristic	Full sample	Facility location			Facility type		
		Outside provincial capital	Within provincial capital	P value	Private	Public	P value
Number	133	53	80		93	40	
Process quality*							
Assessed visual acuity, n (%)	93 (69.9)	35 (66.0)	58 (72.5)	0.43	**58 (62.4)**	**35 (87.5)**	**0.004**
Measured power of existing glasses, n (%)	80 (60.2)	37 (69.8)	43 (53.8)	0.196	**72 (77.4)**	**8 (20.0)**	**<0.001**
Performed automated refraction, n (%)	121 (91.0)	50 (94.3)	71 (88.8)	0.274	**89 (95.7)**	**32 (80.0)**	**0.004**
Performed subjective refraction, n (%)	104 (78.2)	39 (73.6)	65 (81.3)	0.298	73 (78.5)	31 (77.5)	0.9
Measured IPD, n (%)	98 (73.7)	43 (81.1)	55 (68.8)	0.114	70 (75.3)	28 (70.0)	0.531
Offered cycloplegia, n (%)	4 (3.00)	0 (0.00)	4 (5.00)	0.1	**1 (1.10)**	**3 (7.50)**	**0.047**
Made referral for further testing, n (%)	24 (18.1)	8 (15.1)	16 (20.0)	0.475	**1 (1.10)**	**23 (57.5)**	**<0.001**
Total examination time (min), mean (SD)	15.0 (11.7)	16.3 (13.1)	14.2 (10.6)	0.321	15.2 (10.6)	14.6 (13.9)	0.787
Refraction inaccuracy (differing by ≥1 D)							
Final prescription	34 (25.6)	14 (26.4)	20 (25.0)	0.856	20 (21.5)	14 (35.0)	0.103
Commercial aspects							
Cost of examination, mean (SD), US$	1.30 (1.59)	1.34 (1.84)	1.27 (1.40)	0.8	**0.79 (1.29)**	**2.49 (1.58)**	**<0.001**
Suggested price for a pair of non-branded glasses, mean (SD), US$	51.1 (29.7)	53.4 (25.5)	49.5 (32.4)	0.5	**47.8 (28.6)**	**63.7 (31.0)**	**0.022**
Offered warranty on frames, n (%)	16 (14.6)	5 (11.4)	11 (16.7)	0.442	**16 (18.6)**	**0 (0.00)**	**0.022**
Offered warranty on lenses, n (%)	12 (10.9)	3 (6.98)	9 (13.4)	0.294	12 (14.1)	0 (0.00)	0.047

Values in bold are significant at the p<0.05 level.
*According to the preferred practice pattern (PPP) of the American Academy of Ophthalmology (AAO).
IPD, interpupillary distance.

were dispensed as prescribed 100% of the time at the 12 private optical shops offering glasses.

The average cost of a basic eye exam was US$1.30, with a range from 0 to US$5.20 (table 2). The average suggested price for a pair of non-branded glasses was US$51.1. No relationship was found between patient costs and refraction accuracy of optical providers. Compared with the private providers, public hospitals were more expensive for basic eye exams (US$2.49 vs US$0.79, p<0.001) and glasses (US$63.7 vs US$47.8, p=0.022). While 18.6% and 14.1% of private optical facilities offered a warranty on frames and lenses respectively, no public hospitals offered any kind of warranty.

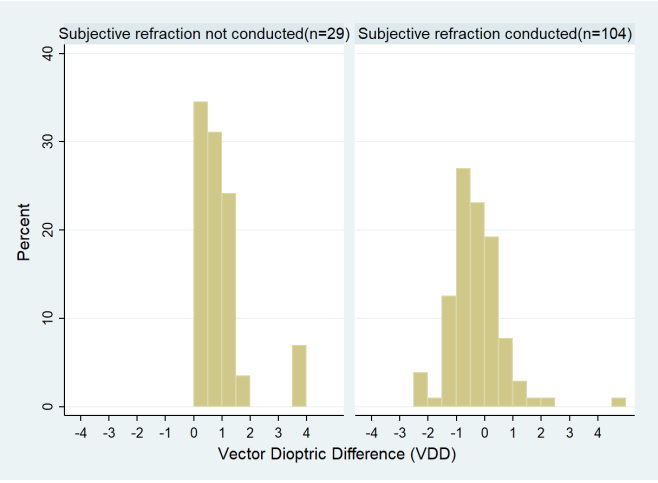

Figure 1 VDD between the final prescription power from local refractionists and the expert optometrist, in the better-seeing eye. A negative value means that the power from the local refractionists was more myopic (minus). VDD, vector dioptric difference.

DISCUSSION

Interactions between incognito SPs and local refractionists revealed shortcomings in the quality of eye care provided in China's public and private optical facilities. Of the items listed by the AAO PPP, examinations of fundamental importance such as assessment of visual acuity, measurement of power of existing glasses and subjective refinement of non-cycloplegic automated refraction were omitted in a quarter to a third of these young, glasses-wearing persons. Fewer than 5% of tested providers offered to perform cycloplegia on SPs, which is important in view of the observed accommodation resulting from lack of subjective refraction in this cohort, and recent evidence that failure to employ cycloplegia results in substantial errors in refraction up to the fifth decade in life in China.[25] Omission of assessments called for in standard international protocols which have been officially adopted in China led to prescriptions inaccurate by ≥1.0 D in a quarter of SPs.

These results for Northwestern China are poor when compared with those reported in two recent studies using SP methodology

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Table 3 Logistic model of potential predictors of local refractionists producing an inaccurate prescription (≥1 D absolute difference from the prescription of the expert refractionist)

	Simple regression analysis		Multiple regression analysis (n=133)		Multiple regression analysis (n=66)*	
Potential predictor	**OR (95% CI)**	**P value**	**OR (95% CI)**	**P value**	**OR (95% CI)**	**P value**
Standard patient characteristics						
Male	0.937 (0.502,1.75)	0.838	1.20 (0.593, 2.42)	0.616	**4.13 (1.19, 14.3)**	**0.025**
Spherical equivalent, >−3.0 D as reference						
≤−3.0 D and >−6.0 D	1.53 (0.786, 2.98)	0.211	1.83 (0.870, 3.86)	0.111	1.63 (0.475, 5.61)	0.436
≤−6.0 D	**2.66 (1.27, 5.56)**	**0.009**	**3.63 (1.61, 8.20)**	**0.002**	4.12 (0.911,18.6)	0.066
Facility characteristics						
Public	**2.01 (1.11, 3.63)**	**0.021**	**2.40 (1.27, 4.52)**	**0.007**	**4.24 (1.25, 14.4)**	**0.021**
Located in the provincial capital	1.06 (0.594, 1.91)	0.834	1.30 (0.70, 2.44)	0.405	1.70 (0.451, 6.40)	0.434
Characteristics of local refractionists						
Male	**2.03 (1.11, 3.69)**	**0.021**	**2.22 (1.18, 4.17)**	**0.013**	**6.52 (2.07, 20.6)**	**0.001**
Education, vs high school	1.15 (0.459, 2.86)	0.770			0.910 (0.298, 2.78)	0.869
Certification, vs middle and high	0.910 (0.385, 2.15)	0.830			1.72 (0.575, 5.15)	0.332
Salary	1.81 (0.769, 4.27)	0.174			1.49 (0.533, 4.18)	0.447

Values in bold are significant at the p<0.05 level.
*Including only those facilities where provider-level demographic and professional data were collected.

to measure content of eye examinations and reproducibility of refractive power among optical providers in the UK.[17 26] Shah's study found that 100% of UK optometrists had results within ±1 D of the benchmark refractive power, consistent with MacKenzie's report that subjective refractions in the UK are reproducible to approximately ±0.75 D when performed by multiple optometrists on patients of different age groups and levels of refractive error.[27] Our observed accuracy rate was also lower (74.4% vs 81.6%) than that reported by Zhou *et al* among rural refractionists in Western China, the only comparable study of which we are aware (though SP methodology was not used).

Our findings indicate that inaccuracies were already prevalent in autorefraction results, 41.3% of which differed by an absolute value of ≥1.0 D in power compared with the benchmark final prescription value from the expert refractionist. Subjective refinement of an automated value by an experienced practitioner is considered a gold standard for refraction, and should tend to reduce errors due to instrument accommodation if done correctly, though that was not the case here. Further, over a fifth (21.8%) of local providers did not perform subjective refraction at all.

More fundamentally, refraction accuracy may be affected by China's limited training of local providers. The poor quality of existing training may in part explain why educational level as well as provider certification were not associated with accuracy of refraction in our study. Longer and better training is needed for China's refractionists, and it is concerning to observe that recently announced ambitious national plans to address refractive error among Chinese children and adolescents have not more strongly emphasised capacity building.[28]

Quality and completeness of eye care service may also be affected by the financial incentives influencing providers in China. Examinations considered ancillary to this aim, such as measurement of visual acuity, though generally considered a cornerstone of eye care,[22] appeared in the current study to be relatively neglected at private facilities, where profits from glass sales may be a crucial revenue stream. The practices of private facilities appeared to be aimed towards the promotion of glass sales, as measurement of the power of existing glasses and use of automated refraction were both more common than in public facilities. In public facilities, where glass sales are not so strongly emphasised, practices consistent with good general eye care, such as measurement of visual acuity and referral for additional care, were more prevalent. Still, inaccurate refraction was more likely at public facilities in our adjusted regression models. Few previous studies have compared public and private facilities in China even without SP methodology,[29 30] and none of which we are aware in the eye care sector.

Professional standards and government regulations are needed to counterbalance financial incentives and to assure that crucial assessments such as measurement of visual acuity and subjective refraction are routinely performed. Existing regulations prohibiting the use of medical cycloplegic agents by non-physicians may in part explain the low proportion of cases in which cycloplegia was offered at private facilities, though not necessarily at public hospitals, where many or most practitioners performing refraction would be expected to be doctors.

Strengths of the current study include the random sampling of a large number of public and private facilities from across a representative province in China, and the use of the gold standard incognito SP approach combined with follow-up questionnaires to capture complete data on providers. Limitations must also be acknowledged. First, SPs in this study were young adults in their mid 20s, so results may not be representative of the quality of care provided to young children and older adults, crucial age groups with regard to the burden of eye disease in China. However, there are practical limitations in the applicability of SP methodology to these more vulnerable groups. Second, due to the number of different automated refractors used by facilities across Shaanxi, it was unavoidable that differences would exist between those used in the baseline and local facility refractions. In general, machines approved for use in China should not have any bias towards results that are higher or lower than the true value, and so we would not expect this difference to lead to bias in our conclusions. Finally, the study sampling frame was limited to Shaanxi province and only prefecture and county-level optical facilities were included. Shaanxi may not be perfectly representative of this socially and geographically complex country, and the primary and tertiary-level facilities which we did not address are also important to the healthcare system.

CONCLUSIONS

To our knowledge, our paper is the first incognito SP study to assess quality of ophthalmic and refractive care in China. Our findings suggest that further government action is needed to

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prepare providers in China to manage the country's current vision care crisis. China has among the highest prevalence of childhood refractive error in the world and rates appear to be rising.[14 31 32] Further improvements in the training and regulation of China's refractionists are needed. China has recently made enormous strides in providing increased access to general healthcare for its residents. Efforts focused on improving vision care will be essential for continued gains in population health.

Correction notice This paper has been amended since it was published online. There was an error in seventh author's surname and first name which had been transposed.

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Contributors YS came up with the concept for this study and designed the study. LZ, JG and QZ set up the study, collected the data and analysed the data. JN and JL drafted the first draft of the paper. SS and NC reviewed and suggested the structure of the manuscript. All authors contributed to the follow-up of the study and the interpretation of the data, and critically reviewed the manuscript.

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Competing interests NC is the director of Research for Orbis International, New York, USA, an organisation involved in promoting eye health in low-resource settings.

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