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Treating uncorrected refractive error in adults in the developing world with autorefractors and ready-made spectacles

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Abstract

Background—To evaluate a method for treating uncorrected refractive error in adults in the developing world.

Design—Prospective, cross-sectional study in outpatient community health centres.

Participants—Eight hundred and forty subjects aged 18 and older from rural villages in Haiti and Belize.

Methods—Undilated refractive error screening exams were conducted over a 5-day period in rural Haiti and Belize using portable autorefractors. Isometric, spherical, ready-made spectacles were provided to patients with bilateral refractive error, astigmatism ≤ 1 dioptre in each eye and visual acuity worse than 6/9 in each eye. Visual acuity was measured with and without corrective spectacles.

Main Outcome Measures—The mean visual improvement and median final visual acuity after treatment with ready-made glasses.

Results—Eight hundred and forty patients aged 18 and older were screened with autorefractors. One hundred and eighty-nine subjects (22.5%) were found to have visually significant bilateral refractive error. Fifty-eight per cent (110/189) of these patients met criteria for treatment with ready-made spectacles. Visual acuity improved an average of 4.2 lines in the better eye and 4.1 lines in the worse eye with corrective glasses. The median visual acuity in the better eye was 6/6 after treatment.

Conclusion—Autorefractors and ready-made spectacles allow for effective treatment of uncorrected refractive error in adults in the developing world.

Keywords

autorefractor; ready-made spectacle; refractive error

Introduction

Uncorrected refractive error is the leading cause of visual impairment in the world, with 98 million to 153 million people affected.^{1,2} The majority of untreated refractive error occurs in developing countries, where there are significant barriers to treatment.^{1,2} These barriers include the lack of trained eye-care personnel, the time-intensive nature of traditional refraction and the cost of customized corrective lenses.^{3–7} An alternative to traditional refraction is the use of autorefractors, which can quickly and accurately measure refractive error without subjective input from the patient.^{8–10} In addition, spherical, isometric, ready-made spectacles have been shown to be an inexpensive alternative to custom lenses for many patients with refractive error.^{11–13} By combining these two technologies, a practical method for correcting refractive error in underserved populations is apparent. The purpose of our prospective study is to evaluate the feasibility of using autorefractors and ready-made glasses for treatment of uncorrected refractive error in adults in the developing world.

Methods

Refractive error screening exams were conducted in rural areas of Haiti and Belize with high rates of poverty and poor access to eye care.^{14,15} Study participants were recruited by local health workers through word-of-mouth and posted bulletins 1 week prior to the study. All comers 18 years of age and older were included in the study. This study was conducted with the approval of the University of Miami Human Subject Research Office (IRB) and the Belize and Haiti Ministries of Health. This research followed the tenets of the Declaration of Helsinki.

Informed consent was obtained for study subjects, and their demographic information was recorded. Undilated refractive error measurements were taken using a Nikon Retinomax 2 (Melville, New York, USA) battery-operated, handheld autorefractor. Visual acuity (VA) without glasses was then tested using an HOTV or tumbling E chart at 10 feet (arithmetic charts based on the Snellen VA chart). Patients who met criteria for treatment with ready-made glasses (described in the following text) were provided with an appropriate pair of spectacles, and their vision was retested with corrective glasses. Participants not meeting criteria for treatment were referred to local eye-care facilities for custom lens fitting. The presence of cataract, pterygia or other sight-limiting disease was determined by penlight examination and undilated direct ophthalmoscopy.

Visually significant bilateral refractive error in this study was defined as:

- Each eye having either sphere $+0.75$ or -0.75 dioptres (D), or cylinder 0.75 D
- VA worse than 6/9 in each eye without glasses
- Lack of significant non-refractive, sight-limiting disease in at least one eye.

Patients with the appropriate refractive error were treated with new, isometric, spherical, ready-made spectacles. Spectacle powers were distributed in half-dioptre increments ranging between -3.50 and $+3.50$ D. The criteria for treatment with glasses were:

- Spherical equivalent +0.75 or -0.75 in each eye
- Spherical equivalent between +0.75 and +3.75 D or -0.75 and -3.75 D in at least one eye
- Astigmatism 1.00 D in at least one eye.

Patients were given glasses powered to match the eye with the spherical equivalent closest to zero. Patients with unilateral astigmatism >1.00 D were given glasses based on the spherical equivalent of the less astigmatic eye.

The primary outcomes of the study were the mean visual improvement and median final VA in each eye after treatment with ready-made glasses. Secondary outcomes included the prevalence of bilateral refractive error in our study population, including refractive error suitable for treatment with spherical ready-made lenses.

Descriptive statistics were calculated for patient demographics. Snellen VA measurements were converted to logMAR equivalents for the purpose of statistical analysis, with count fingers, hand motion, light perception and no light perception (NLP) vision factored on the logarithmic scale as 2.3, 2.6, 3.0 and 4.0, respectively.^{16,17} The comparison between VA with and without corrective eyeglasses was performed using paired *t*-tests. Comparative statistics between Haiti and Belize study populations were performed using Pearson χ^2 -test and 2-sided Student's *t*-test.

Results

A total of 840 patients were screened for refractive error over a 5-day period in both Haiti and Belize. The demographics of the study participants are shown in Table 1. The mean uncorrected VA for the entire study population was 6/12.3 (median: 6/7.5, range: 6/6–NLP) in the better eye and 6/19.2 (median: 6/9, range: 6/6–NLP) in the worse eye. The spherical equivalents for all eyes are shown in Figure 1. Thirty-eight (4.5%) patients were noted to have bilateral, non-refractive, sight-limiting disease such as dense cataracts, corneal scars or large pterygia.

Of the 840 patients screened, 189 (22.5%) had visually significant bilateral refractive error. Among them, 110 patients (58.2%) had refractive error suitable for treatment with ready-made lenses. The remainder of the patients with bilateral refractive error had either astigmatism >1 D in both eyes ($n = 34$, 18%), spherical equivalent +4 D or -4 D in both eyes ($n = 8$, 4%), a mix of high astigmatism and spherical equivalent ($n = 4$, 2%), were monocular with high astigmatism or spherical equivalent in their seeing eye ($n = 3$, 2%) or had at least one eye with spherical equivalent $<+/-0.75$ D ($n = 30$, 16%) (Table 2).

The median uncorrected VA of patients treated with ready-made glasses was 6/18 in the better eye and 6/24 in the worse eye (Table 3). After correction with ready-made lenses, VA improved an average of 4.2 lines in the better eye ($P < 0.001$, paired *t*-test) and 4.1 lines in the worse eye ($P < 0.001$, paired *t*-test). The median final VA was 6/6 in the better eye and 6/9 in the worse eye.

In patients treated with ready-made glasses, 103/110 (94%) had vision 6/12 in their better eye following treatment. Two (2%) subjects experienced worsening of their VA in the better eye and seven (6%) subjects had worsening of vision in their worse eye with ready-made lenses. These eyes lost an average of 1.9 lines of vision with a median final VA of 6/24.

The prevalence of bilateral refractive error among individuals presenting for screening was not significantly different between the Haiti and Belize cohort (25% vs. 21%, $P = 0.17$, χ^2 -test). No significant difference existed between the Haiti and Belize study populations with regard to percentage of subjects with refractive error treated with ready-made glasses (61% vs. 71%, $P = 0.07$, χ^2 -test), lines of VA improvement or final VA in the better or worse eye (Table 4).

Discussion

Our research showed that a large portion of the refractive error in our study population can be effectively diagnosed, measured and treated using autorefractors and ready-made glasses. Of the 189 patients with bilateral refractive error in our study population, 110 (58%) were treated with ready-made glasses. Patients who received ready-made glasses experienced a mean 4.2 line improvement in VA, bringing them to a median final acuity of 6/6 in their better eye. These data demonstrate the large impact this method may have on improving VA loss because of refractive error. The findings were consistent between the Belize and Haiti arms of this study, suggesting that this method may be effective in a wide range of demographics.

Despite the success of this method, limitations to the use of autorefractors and ready-made glasses in the developing world exist. Autorefractor accuracy may be reduced in cases of irregular astigmatism (such as corneal scarring or pterygium), dense cataract or miosis. Furthermore, young patients without cycloplegia may register overly myopic because of accommodation during autorefraction.¹⁸ Accommodation should be suspected in cases of inappropriately myopic, fluctuating or low-reliability measurements. Lastly, patients may not achieve their best-corrected VA without subjective refinement of autorefractor measurements.

Ready-made lenses also have their limitations. Because of their spherical design, these glasses cannot treat refractive error because of high astigmatism, which accounted for approximately one-quarter of bilateral refractive error in our study population. Ready-made spectacles also do not treat anisometropia, given that they are made with the same spherical power in both eyes. On the other hand, induced anisokonia is not considered a limitation as patients experience no change in their anisometropia with treatment. In addition, these glasses are manufactured with a generic pupillary distance, which may induce horizontal prism when fit to patients with pupillary distances away from the norm. This in turn could lead to headaches or manifest tropias in susceptible patients.

Our study is limited by the fact that study personnel were not masked to the treatment status of our patients, a potential source of bias when testing VA. Furthermore, patients with visual symptoms were more likely to attend screenings, introducing selection bias. Lastly, our

study was limited to a single interventional visit, preventing any measurement of patient compliance with glasses or future sustainability of our methods.

In conclusion, autorefractors and ready-made spectacles allow for effective treatment of uncorrected refractive error in adults in Haiti and Belize. Although this method does not benefit all participants, we recognize that we are not competing against the gold standard: a traditional refraction followed by provision of custom-made lenses by a skilled eye-care professional. Instead, we are competing against the absence of any spectacle correction, which is the level of care that millions of people around the world receive for their disabling refractive error. Poor VA impacts work productivity, safety and other parameters of quality of life. By simplifying methods and sacrificing a small amount of accuracy, autorefractors and ready-made lenses have the potential to improve the lives of millions who would otherwise receive no treatment for their uncorrected refractive error.

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Figure 1.

Spherical equivalent of study eyes. Note: -4 indicates spherical equivalent less than or equal to -4; and 4 indicates spherical equivalent more than or equal to 4.

Table 1

Patient demographics

(n = 840)	Belize (n = 289)	Haiti (n = 551)	Combined
Mean age (range)	45 (18–88)	47 (18–102)	46 (18–102)
Gender			
Male	113 (39%)	181 (33%)	294 (35%)
Female	176 (61%)	370 (67%)	546 (65%)
Ethnicity			
Mayan	259 (90%)	NA	259 (31%)
Haitian (Black)	NA	551 (100%)	551 (66%)
Other	30 (10%)	NA	30 (4%)

Table 2

Patients with bilateral refractive error not treated with ready-made glasses

	Belize	Haiti	Combined
Number of patients with bilateral refractive error not treated with ready-made glasses	26/73 (36%)	53/116 (46%)	79/189 (42%)
Cyl > 1 D in both eyes	9 (12%)	25 (22%)	34 (18%)
SE ≥ 4 D in both eyes	3 (4%)	5 (4%)	8 (4%)
Cyl > 1 D and SE ≥ 4 D in both eyes	0	4 (3%)	4 (2%)
Monocular patient with SE ≥ 4 D and/or Cyl > 1 D	2 (3%)	1 (1%)	3 (2%)
SE < 0.75 D in at least one eye	12 (16%)	18 (16%)	30 (16%)

Cyl, cylinder power; D, dioptries; SE, spherical equivalent.

Table 3

Mean improvement and median final visual acuity after treatment with ready-made glasses in combined Belize and Haiti study populations

Treated patients (<i>n</i> = 192)	Untreated	With ready-made glasses	Mean lines improvement $\pm$ SD	<i>P</i> -value*
Better eye median VA	6/18 mean: 6/19.2 range: 6/12–6/60	6/6 mean: 6/7.8 range: 6/6–6/60	4.2 $\pm$ 2.5	<0.001
Worse eye median VA	6/24 mean: 6/29.1 range: 6/12–CF	6/9 mean: 6/10.8 range: 6/6–CF	4.1 $\pm$ 2.8	<0.001

* Paired *t*-test. CF, count fingers; VA, visual acuity; SD, standard deviation.

Table 4

Comparison of mean improvement and final visual acuity after treatment with ready-made glasses in Haiti and Belize

<i>n</i> = 110	Belize (<i>n</i> = 47)		Haiti (<i>n</i> = 63)		<i>P</i> -value (Belize vs. Haiti)	
Better eye	<i>N</i>	<i>N</i>				
Median untreated VA	45	6/18	63	6/18	0.92 [†]	
Mean untreated VA logMAR ± SD	45	0.51 ± 0.21	63	0.51 ± 0.20	0.98 [‡]	
Median treated VA	43	6/7.5	60	6/6	0.25 [†]	
Mean treated VA logMAR ± SD	43	0.12 ± 0.16	60	0.10 ± 0.17	0.44 [‡]	
Mean lines improvement ± SD	43	4.0 ± 2.5	60	4.4 ± 2.6	0.41 [‡]	
<i>P</i> -value [§]	NA	<0.001 [¶]	NA	<0.001 [¶]	NA	
<i>P</i> -value [§]	NA	<0.001 ^{††}	NA	<0.001 ^{††}	NA	
Worse eye						
Median untreated VA	45	6/24	63	6/21	0.59 [†]	
Mean untreated VA logMAR ± SD	45	0.71 ± 0.42	63	0.67 ± 0.42	0.70 [‡]	
Median treated VA	42	6/9	60	6/9	0.89 [†]	
Mean treated VA logMAR ± SD	42	0.24 ± 0.25	60	0.28 ± 0.43	0.58 [‡]	
Lines improvement ± SD	42	4.2 ± 2.9	60	4.1 ± 2.8	0.95 [‡]	
<i>P</i> -value [§]	NA	<0.001 [¶]	NA	<0.001 [¶]	NA	
<i>P</i> -value [§]	NA	<0.001 ^{††}	NA	<0.001 ^{††}	NA	

[†] Mann-Whitney test for the Snellen equivalents between Belize and Haiti.

[‡] Student's *t*-test for logMAR between Belize and Haiti.

[§] Mean treated *versus* untreated VA.

[¶] Paired *t*-test for logMAR between untreated and treated.

^{††} Wilcoxon signed ranks test for the Snellen equivalents between untreated and treated. SD, standard deviation.