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The innovative self-adjustable Adspecs™

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Abstract

A method of self-refraction, based on an old concept implemented with the aid of modern technology, is spectacles with adjustable lenses. The spectacle design is referred to as the Adspecs™. The advantage of the Adspecs is that the wearer can adjust the powers of the lenses to suit his or her visual needs. The power is spherical and ranges from −6 to 6 D. Studies were undertaken in Ghana and South Africa. Subjects were instructed under supervision to adjust the powers of the Adspecs as accurately as possible to correct their vision and obtain the best visual acuity possible. An optometrist then refracted the patients and the results were then compared. For the right eyes, the mean stigmatic coefficient difference for distance vision was −0.13 D and the standard deviation 0.89 D. For the left eyes, the mean was −0.24 D and the standard deviation 0.91 D. For near vision, the mean for the right eyes was −0.27 D and standard deviation 1.07 D, and for the left eyes, the mean was −0.27 D and standard deviation 1.23 D. The standard deviations for the means (at distance and near) for left eyes were slightly greater than for the right eyes.

Introduction

There are approximately 45 million blind people worldwide and an additional 180 million people with low or impaired vision[1]. 90% of all global blindness is found in developing countries. Studies done in 2000 estimate that approximately 2.3 billion people worldwide have refractive error causing vision loss, but only 1.8 billion have access to affordable vision correction, leaving approximately 500 million with uncompensated refractive error. According to Schwab and Steinkuller uncompensated refractive errors are a leading cause of visual disability in these populations[2]. Cataracts are the leading cause of blindness worldwide that can be rectified.

Infrastructure, work force, finance and the lack of expertise are major problems in trying to solve vision correction in developing countries throughout the world. This also applies to disadvantaged people in developed countries. Many studies have shown the need for vision correction in both first- and third-world countries. Delivering such a service by current conventional methods places tremendous pressure on available resources, foremost amongst which are manpower and time. Other effective and inexpensive methods must be introduced. Portable autorefractors are one method available and have proven useful where no electricity is available.

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In a recent outreach project in Paraguay, Lenscrafters, an American optical company examined 17 000 subjects for vision correction and pathology over a period of five days[3]. Their team consisted of five optometrists using six autorefractors, two students, 25 technicians and 12 translators. Examining 17 000 subjects over five days only would have been very difficult to achieve without the use of the autorefractors.

Studies done on data received from the Phelophepa primary health-care train in South Africa during 2001 and 2002 showed that of approximately 30 000 patients examined, 73% needed correction for astigmatism of 1 D or less[4]. Approximately 23% showed correction between 1.25 and 2 D, 3% between 2.25 and 3 D and 1% greater than 3 D. The train, however, has a fully equipped laboratory so astigmatic lenses are dispensed. This, however, is not the situation in many other countries where prescriptions are based upon nearest equivalent sphere (NES) and stigmatic (that is, spherical) lenses are dispensed.

Self-testing instruments are being used under supervision for vision correction. The Focomotor, a new type of refractometer developed by Chris Kuether, Director of Technical services, at the University of Houston College of Optometry, Houston Texas, USA uses Badal Optometer optics[5]. Patients view a target through the instrument and then adjust the focusing mechanism until the best focus is achieved. The instrument records the NES. Astigmatic errors can also be determined using a stenopaic slit and axis scale, which is attached to the end of the instrument. It is an inexpensive instrument that needs no power to operate and thus is ideal for areas that have no electricity. The instrument has proved successful and is currently being used in Burma, India, Mexico, Thailand, Brazil, Tanzania and Texas in the USA[6]. Using this method of refraction, spectacles still have to be made and this requires cutting and fitting of lenses.

Another method of self-refraction, based on an old concept implemented with the aid of modern technology, is spectacles with adjustable lenses. The spectacle frame, of which the

Figure 1. The Adspecs™

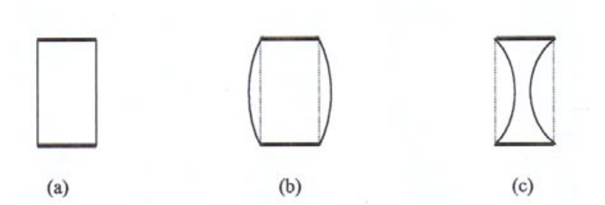

Figure 2. Forms assumed by the membrane in the Adspecs. (a) Flat, (b) equi-convex, and (c) equiconcave form.

lens shape is circular, is made from a cellulose acetate material. Inside the plastic eyewire, which is approximately 7 mm in diameter is a circular metal attachment, 42 mm in diameter, which holds two sealed expandable transparent membranes intact. The volume between them is filled with a liquid of refractive index 1.579 by means of syringes that are attached to either temple of the frame[7]. The concept is illustrated in Figure 1. In its flat form the power of the lens is plano (Figure 2a). As more liquid is injected into the chamber, the membranes expand becoming convex in shape producing a lens of positive power (Figure 2b). When the liquid is removed from its Plano form, it becomes concave in shape producing a lens of negative power (Figure 2c). The spectacle design is referred to as the Adspecs.™ The advantage of the Adspecs is that the wearer can adjust the powers of the lenses to suit their visual needs. The power ranges from 6 to – 6 D. It does not correct for astigmatism.

Interferometry tests done on the expandable membranes showed that the film thickness varied by less than approximately 4 microns per 10 mm linear displacement across its surface and this produced a wavefront error of less than approximately 40% compared to the error produced by a human eye[7].

The Adspecs were developed by Adaptive Eyecare Limited, a company based in Oxford, England and headed by Professor Joshua Silver, an atomic physicist at the University of Oxford. The purpose of the Adspecs is to provide functional vision at a low cost, under supervision from a qualified assistant, to first and third world countries. Studies were carried out in some developing countries namely Malawi, Ghana, Nepal and South Africa. Subjects were instructed under supervision to adjust the powers of the Adspecs as accurately as possible to correct their vision and obtain the best visual acuity possible. The author was invited to partake in the studies in all the above-mentioned countries. The studies done for this article were carried out in Durban in South Africa and Hohoe, a small town in the Volta region of Ghana.

Methods

Durban (South Africa)

Twenty-eight subjects from a rural area approximately 50 km outside Durban were examined. They were split up into two categories, under the age of 40 years and over 40. Fourteen subjects were under 40 and 14 were over 40. The criteria for the study were that the subjects have an uncompensated distance visual acuity (DVA) of 6/9 or worse in the better eye, and supjects were not spectacle wearers.

The tests were performed in an office building in central Durban. Uncompensated monocular and binocular DVA were measured and recorded. No uncompensated visual acuity measurements were recorded for near vision. The subjects then self-adjusted the Adspecs (under instructions, firstly from a moderator who was part of the recruitment team and also a translator, and secondly from an optometrist, monocularly and then binocularly to see if any improvements on the visual acuity could be made. The adjusted Adspecs powers were then measured on the vertometer. The optometrist then refracted all the subjects. For the analysis of the results, only those recorded by the optometrist were used.

No subjects were screened for pathology. An 'illiterate E' visual acuity test chart was used at a distance of six metres for the acuity measurements. The acuity measurements were recorded by the line number that the subject could read and then converted to decimal notation. The cut off point for the acuity was 20/20 (or 1 in decimal notation). The near visual acuities were measured at a distance of 40 cm.

Hohoe (Ghana)

In Ghana 30 subjects were examined. They were split up into two categories, under the age of 40 years and over 40 years. Fourteen subjects were under 40 and 16 were over 40. The author and two other optometrists from Ghana performed the subjective and Adspecs refractions.

The same methods were used as for Durban, but now the uncompensated near VA's for the over forty category were recorded. Uncompensated VA's and compensated Adspecs VA's were done indoors. Compensated Adspecs and the optometrists refractions were then repeated outdoors. since the lighting in the room we worked in was not entirely up to standard. (The lighting was poor and deteriorated as time progressed due to the changing weather. The minimum illuminance for externally illuminated charts is 480 lux.[8] The illumination on occasions was as low as 120 lux. It rained just about everyday and the lighting got worse. I suspect that a lot of the distance and near uncompensated visual acuity measurements were suspect, especially for the over 40 group.) Twice the optometrists repeated the Adspecs measurements for the distance and near VA's. The second measurements obtained were used for the analysis. These second Adspecs measurements were not always the highest positive values.

The self-adjustment procedure

The Adspecs is preset with a power of 4 D in both eyes to ensure that accommodation is relaxed. For distance vision, the subject views the chart at a distance of six metres. The subject is instructed to start adjusting the Adspecs by turning the dial of the syringe on the temples of the Adspecs either in a forward or backward direction (backwards producing more negative power and forwards more positive) monocularly until the best acuity is achieved. Both eyes are open, but the one not being tested, occluded. To avoid over correction, especially with the younger subjects, they were asked to adjust until the best VA was obtained, then re-adjust very slightly in the forward direction (to add more positive power) until the target just blurs, then re-adjust a small amount until it clears.

For near vision, the subjects adjusted the Adspecs binocularly looking at a near vision chart at a distance of 40 cm with their distance adjustment as a starting point.

Results

Durban

For this particular study, visual acuity comparisons were done binocularly. Figure 3 shows the comparison for the under 40 category, the binocular distance uncompensated VA's shown with the cross (+), the compensated Adspecs (x) and the optometrist's (o). With the exception of subjects number 6, 11 and 13, all the others had 20/20 uncompensated VA. Only subject number 13 failed to obtain 20/20 vision through the Adspecs. However, for subjects number 6 and 11, the Adspecs improved the uncompensated VA's from 0.66 to 1. This sample however, did not fit the criteria as requested.

Figure 4 shows the comparisons for the over 40 category. 20/20 vision could not be obtained through the Adspecs nor with the optometrist's refractions for subjects 7, 8, 11, 12 and 13. However, VA's did improve through the Adspecs for subjects number 5 and 9 (from 0.66 to 1), 10 (0.4 to 0.66) and 12 which corresponded with the optometrist's (0.2 to 0.3). Subject number 11 experienced a reduction in VA through the Adspecs (0.4 to 0.3). Subject number 3 experienced no improvement through the Adspecs when compared with the uncompensated VA. Subjects number 7 and 13 obtained the same VA as the uncompensated and optometrist's (0.66). Subject number 12 obtained an improvement from 0.2 to 0.3 through the Adspecs, which corresponded with the optometrist's.

Figure 5 shows the comparison for the over 40 binocular near VA's. Other than for subjects number 7, 8, 11 and 12, 20/20 vision was obtained through the Adspecs. Subject number 7 obtained the same VA (0.66) through the Adspecs as with the optometrist. Unfortunately, no uncompensated VA's were recorded for this category, so it was difficult to establish if the Adspecs had any effect on subjects number 7, 8, 11 and 12.

Hohoe (Ghana)

Figure 6 shows a comparison for the under 40 category, the binocular distance uncompensated VA's shown with the cross (+), the compensated Adspecs (x) and the optometrist's (o). Other than for subject number 9, all the others experienced an increase in VA through the Adspecs and obtained 20/20 vision. However, Subject number 9 DVA did improve from 0.4 to 0.66 through the Adspecs.

Figure 7 shows the comparison for the over 40 category. Subjects 2, 3, 4, 5, 8, 9, 10 and 14 obtained 20/20 vision through the Adspecs. For subjects number 1 (from 0.2 to 0.4), 7 (0.3 to 0.6), 11 (0.2 to 0.66), and 16 (0.3 to 0.4) where 20/20 vision could not be obtained, visual acuity through the Adspecs corresponded with the optometrist's. Visual acuity could not be improved through the Adspecs for subject number 6 (0.2). Subject number 13 somehow obtained a better uncompensated acuity (0.5) than the compensated Adspecs and optometrist's (0.4). Although 20/20 vision was not obtained for subject number 15, the visual acuity did however improve through the Adspecs from 0.4 to 0.66. For subject 12, visual acuity through the Adspecs decreased from 0.3 to 0.1.

Figure 8 shows the comparison for the over 40 binocular near visual acuities. Eleven of the 16 subjects experienced an increase in VA through the Adspecs and obtained 20/20 vision.

Although no improvement was obtained for subject number 1 through the Adspecs, the VA cor-

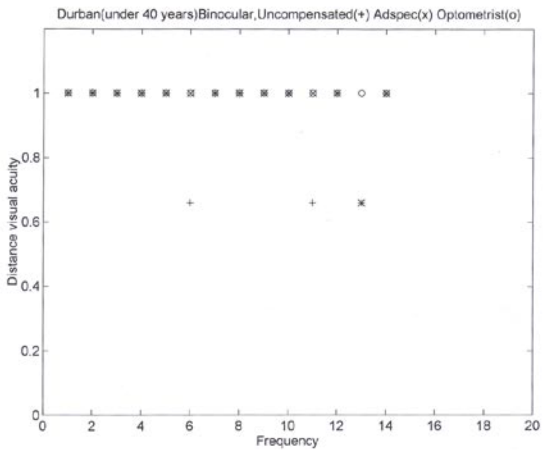

Figure 3. Comparison of distance visual acuities in the Durban under 40 category. The binocular distance uncompensated VA are shown by means of +, the compensated Adspecs VA by x and the optometrist's compensated VA by o.

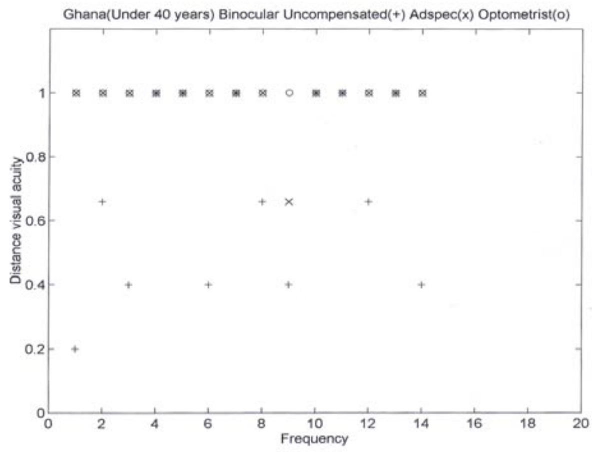

Figure 6. Comparison of distance visual acuities in the Ghana under 40 category. The binocular distance uncompensated VA are shown by means of +, the compensated Adspecs VA by x and the optometrist's compensated VA by o.

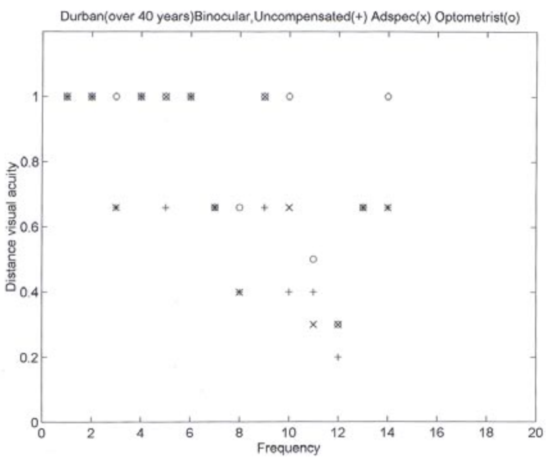

Figure 4. Comparison of distance visual acuities. The details are the same as for Figure 3 but for the over 40 category.

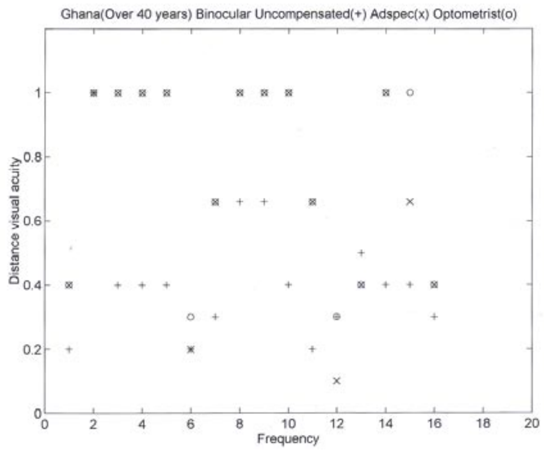

Figure 7. Comparison of distance visual acuities. The details are the same as for Figure 6 but for the over 40 category.

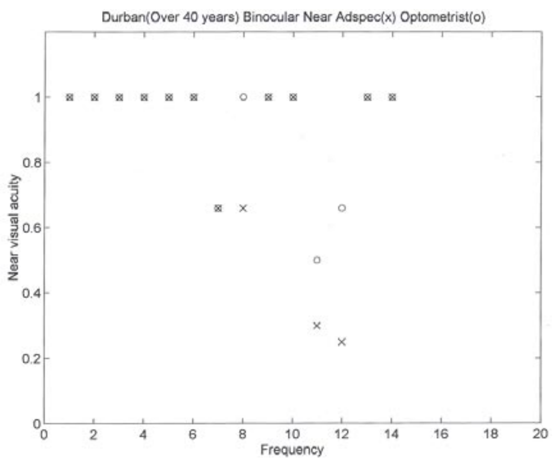

Figure 5. Comparison of distance visual acuities. The details are the same as for Figure 4 but for near targets.

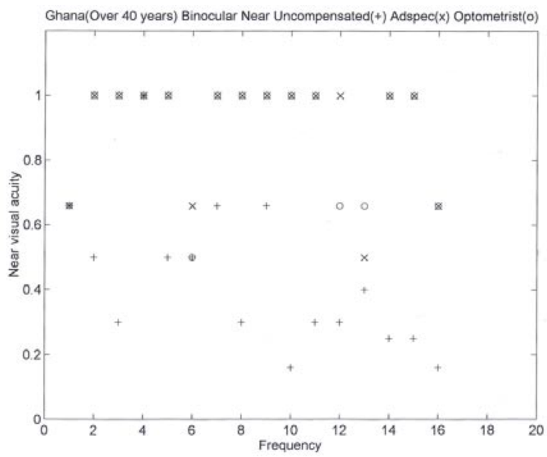

Figure 8. Comparison of visual acuities. The details are the same as for Figure 7 but for near targets

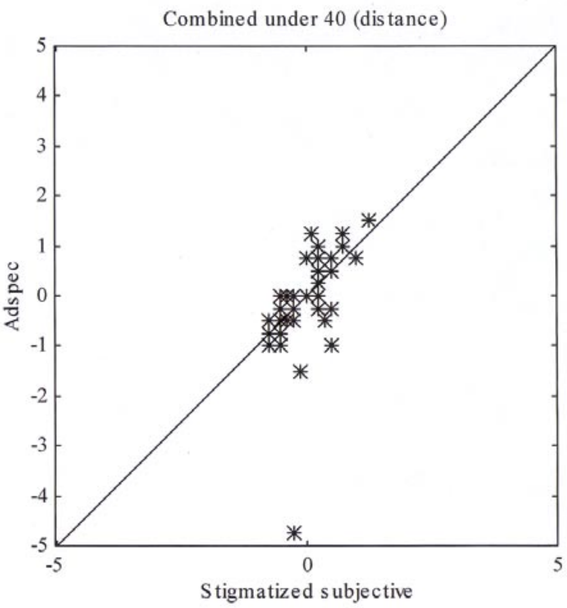

Figure 9. Combined data points for distance (right and left eyes), the Adspecs (vertical axis) and optometrist's stigmatic coefficient refractions (horizontal axis), plotted for the Durban and Ghana under forty category.

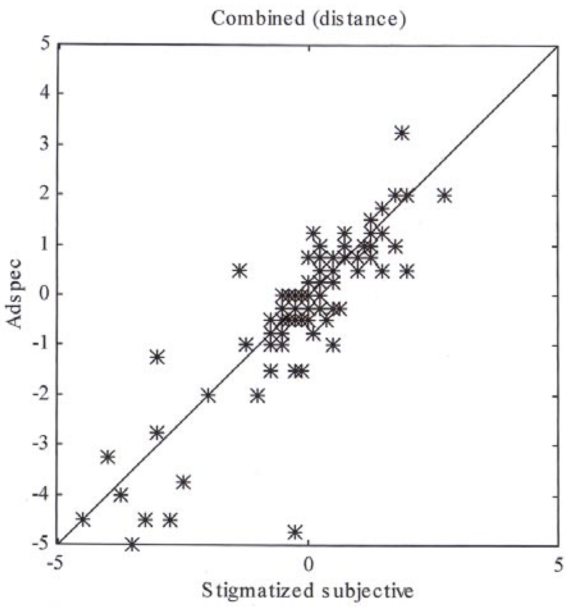

Figure 11. Combined data points for distance (right and left eyes), the Adspecs (verical axis) and optometrist's stigmatic coefficients refractions (horizontal axis), plotted for the Durban and Ghana under and over forty category.

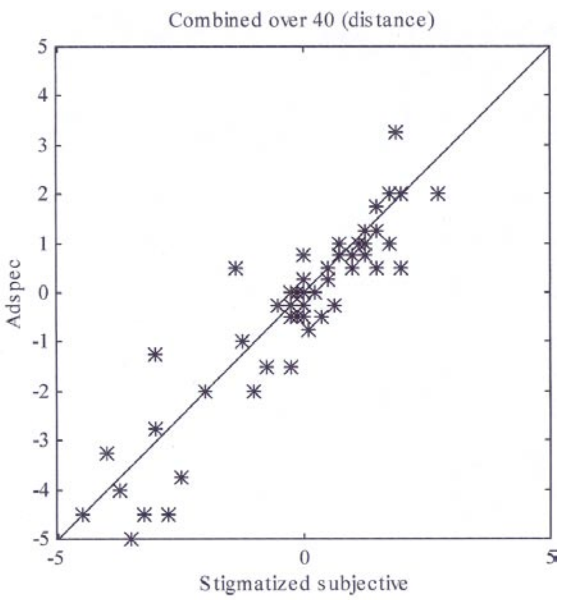

Figure 10. Combined data points for distance (right and left eyes), the Adspecs (vertical axis) and optometrist's stigmatic coefficient refractions (horizontal axis), plotted for the Durban and Ghana over forty category.

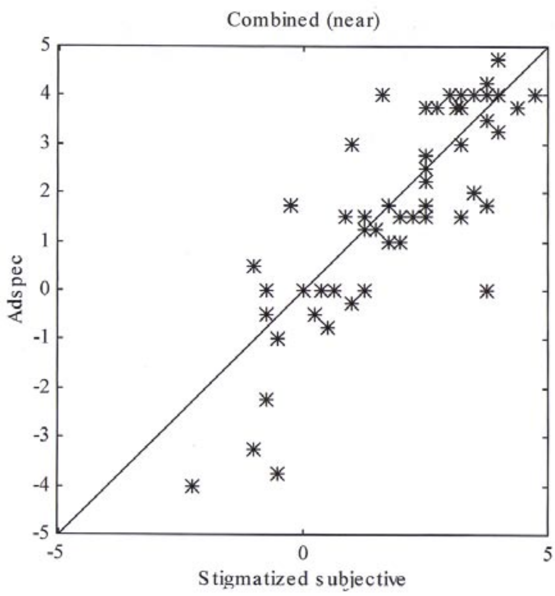

Figure 12. Combined data points for near (right and left eyes), the Adspecs (vertical axis) and the optometrist's stigmatic coefficient refraction's (horizontal axis), plotted for the Durban and Ghana over forty category.

responded with the optometrist's (0.66). Subject number 6 somehow experienced a decrease in VA (from 0.66 to 0.5) through the Adspecs and the optometrist's refraction. Subject number 12 obtained 20/20 vision through the Adspecs whereas the optometrist only obtained 0.66. Subject number 13 and 16 did however obtain an improvement in VA through the Adspecs from 0.4 to 0.5 and from 0.2 to 0.66 respectively, and subject number 16 improved from 0.2 to 0.66 with the Adspecs and optometrist's findings.

Discussion

Accuracy of the Adspecs

The optometrists' refractions were converted to the nearest equivalent sphere (stigmatic[9] coefficient) and then compared with the self-adjusted Adspecs correction.

Graphs of the Adspecs self-adjustment powers (y-axis, vertical) were plotted against the optometrists' stigmatic coefficient refractions (x-axis, horizontal). All the optometrists' stigmatic coefficient data points and self-adjustments were plotted between – 5 D and 5 D. If the self-adjustments were all perfect, all points would lie on the line $y = x$. Figures 9 and 10 show the combined under-40 DVA category (for both right and left eyes) for Durban and Ghana and over-40 category respectively. Figure 11 shows the combined distance (both right and left eyes, under and over 40 categories for Durban and Ghana) points.

Figure 12 shows the combined near points. Asterisks for the distance refractions tend to cluster more closely to the diagonal (Figure 11) than for near refractions (Figure 12).

The distance stigmatic coefficients for all subjects as determined by the optometrists were subtracted from the corresponding results measured from the Adspecs and a mean sample difference and standard deviation were calculated. For the right eyes, the mean stigmatic coefficient difference was – 0.13 D and the standard deviation 0.89 D. For the left eyes, the mean was – 0.24 D and the standard deviation 0.91 D. The variation for the left eyes was slightly greater. Thus, on average, the Adspecs result seemed a little more negative in power than found by the optometrists although this difference is probably not clinically significant.

For the near results, the mean for the right eyes was – 0.27 D and standard deviation 1.07 D, and for the left eyes, the mean was – 0.27 D and standard deviation 1.23 D. The standard deviations for the means (at distance and near) for left eyes were slightly greater than for right eyes. The standard deviations for the distance means were less than that for the near means.

As previously mentioned, working conditions in Ghana were not ideal. Uncompensated visual acuities were measured indoors by the moderator while the lighting was good. The lighting deteriorated as the day progressed.

The optometrists' refractions were performed last. Maybe this was the reason why the results for the over 40 near category (Figure 8) showed better results for the Adspecs than the optometrist's for subjects number 6 and 12.

When working with the Adspecs it is imperative that a detailed set of instructions is provided to the instructor or patient or both and that they are carried out as accurately as possible. Working with the elderly rural population was much more difficult than with the younger population. They tended to be more nervous, sometimes found the Adspecs more difficult to adjust and were sometimes reluctant to turn the dials on the syringes. It was more difficult to communicate with the elderly and perhaps they did not always understand what was expected of them.

Conclusion

The results indicate that in almost all subjects their DVA and NVA's improved with the Adspecs in comparison with their uncompensated visual acuities. Although acuities did improve, this does not suggest that comfortable vision would be present for all the subjects over long periods. Sample sizes were small and further investigation is necessary to improve, if not, perfect the self-adjustment procedure.

The main aim of the Adpecs™ project is to provide low cost spectacles, under strict supervision, that are functional to anyone who is interested and most importantly to improve the quality of life of the disadvantaged population.

Acknowledgements

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