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A preliminary assessment of the Welch Allyn Suresight 14000 handheld autorefractor

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Abstract

In an effort to assess the accuracy of the Welch Allyn Suresight 14000 handheld autorefractor, one eye of 84 students at Pacific University College of Optometry were refracted with the Suresight, the Canon RK-5 Autorefractor-Keratometer (a stationary device), static retinoscopy, and subjective refraction. The results obtained with the Suresight were then compared to the other methods. When compared to results obtained through subjective refraction, it was observed that the sphere values provided by the Suresight were within 0.50 D in 54.8% of subjects. This percentage remained fairly constant (52.8%), even in subjects with low refractive errors (between+ 1.00 and -1.00), indicating that the percentage of deviation between the two methods is greater in individuals with small amounts of myopia or hyperopia. The cylinder power in subjects with greater than 0. 75 D of cylinder was within 0.50 D in 84% of subjects. Cylinder axis was within 15 degrees in only 58.8% of these individuals. Regression analysis demonstrated that both Canon autorefraction and retinoscopy provided better predictions of subjective refraction (r~0.9) than predictions obtained with Suresight (r2=0.77); although Suresight measures tended to be more accurate for higher refractive errors. Both Canon and Suresight were approximately equal in terms of repeatability. The results indicate that the Welch Allyn Suresight falls slightly short of the Canon RK-5 and retinoscopy in its ability to accurately predict the subjective refraction. However, its portability and ease of use make it a potentially useful tool in practices with a large pediatric and/or disabled patient base.

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A Preliminary Assessment of the Welch Allyn Suresight 14000 Handheld Autorefractor

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ABSTRACT

In an effort to assess the accuracy of the Welch Allyn Suresight 14000 handheld autorefractor, one eye of 84 students at Pacific University College of Optometry were refracted with the Suresight, the Canon RK-5 Autorefractor-Keratometer (a stationary device), static retinoscopy, and subjective refraction. The results obtained with the Suresight were then compared to the other methods. When compared to results obtained through subjective refraction, it was observed that the sphere values provided by the Suresight were within 0.50 D in 54.8% of subjects. This percentage remained fairly constant (52.8%), even in subjects with low refractive errors (between +1.00 and -1.00), indicating that the percentage of deviation between the two methods is greater in individuals with small amounts of myopia or hyperopia. The cylinder power in subjects with greater than 0.75 D of cylinder was within 0.50 D in 84% of subjects. Cylinder axis was within 15 degrees in only 58.8% of these individuals. Regression analysis demonstrated that both Canon autorefraction and retinoscopy provided better predictions of subjective refraction ($r^2>0.9$) than predictions obtained with Suresight ($r^2=0.77$); although Suresight measures tended to be more accurate for higher refractive errors. Both Canon and Suresight were approximately equal in terms of repeatability. The results indicate that the Welch Allyn Suresight falls slightly short of the Canon RK-5 and retinoscopy in its ability to accurately predict the subjective refraction. However, its portability and ease of use make it a potentially useful tool in practices with a large pediatric and/or disabled patient base.

Keywords: Welch Allyn Suresight 14000, autorefractor, refraction, Canon RK-5, retinoscopy, hyperopia, myopia, cylinder

INTRODUCTION

The Welch Allyn Suresight 14000 handheld autorefractor is one of the recent additions to the growing market of handheld refractive devices. It functions using laser technology and Shack-Hartmann wavefront analysis. The device is pointed towards the patient's pupil using the instrument's viewport and illuminated crosshairs. Reflected light from the eye enters the device and into a grid of rows and columns of lenses. Based on the eye's refraction, a pattern of light is formed on a sensor, which uses an algorithm to determine the eye's sphere, cylinder power, and axis. The measurement range of the device is +6.00 to -5.00 diopters of sphere and up to 3.00 diopters of cylinder. Measurements are taken in 0.25 diopter increments and cylinder axis is rounded to the nearest degree.

The manufacturer claims that the device may be used in any lighting condition, and the patient does not have to be sitting in a standard exam chair. The user is discouraged from using the device in rooms where a window is located either behind or directly in front of the instrument. Based on the range of locations where it can be used and the portability allowed by its size (it weighs only 2 pounds), the Suresight has been marketed as a very versatile device for practitioners who frequently perform on-site screenings or which have a large pediatric and geriatric patient base.

One of the appeals of the Suresight is its relatively large working distance, especially beneficial when refracting pediatric or physically disabled patients. It is designed to be used at a distance of 35 cm from the patient. To ensure that this precise distance is achieved, the device contains a distance sensor on the front of the unit which produces beeping sounds, which are low-pitched and long in duration if the distance is too great and short and high-pitched if the practitioner is too close to the patient. The manufacturer also claims that these sounds serve to engage the patient during test taking, in an effort to ensure that accommodation is held in check. When the proper test distance is reached, a long, continuous beep is heard. High pitched chirping noises are produced when the instrument is in the process of taking its measurements and a distinct "tah-dah" is emitted when the testing is complete.

The Suresight takes between 5 and 8 continuous readings over the span of 2.4 seconds, which are stored and averaged for each eye. A confidence rating is then determined on a scale of 1 to 9 based on the uniformity of the measurements taken. To ensure greater accuracy, the manufacturer recommends that only results with a confidence rating of six or higher be accepted. The Suresight allows a sequential measurement of the left and right eye by pressing one button prior to beginning the measurement, or it can be manually set to measure either eye using two separate buttons. During measurement, the patient fixates a small red light that is seen in the middle of circling green lights when the instrument is aligned properly.

Among the features of the Suresight is a button which is pressed prior to performing an autorefraction on pediatric patients. The calibration of the instrument is adjusted in an effort to compensate for the variable accommodation in younger children. The manufacturer recommends that this feature be utilized with all non-cyclopleged patients 6 and younger.

When all measurements have been obtained, the results are displayed on an LCD screen located on the back of the device. Included among the data are the sphere value, the cylinder value, the axis location, and the confidence rating for each eye. If the patient's refractive error is beyond the range of the instrument a +9.99 or -9.99 is displayed, depending on if the individual is hyperopic or myopic. (This allows the practitioner to perform an over-refraction with the necessary plus or minus lenses in place.) The results can then be copied by hand into the patient's records, or the data can be transmitted to a wireless printer, included with the device, via an infrared beam emitted from a source on the front side of the unit. The Suresight also includes an RS-232 port on the bottom of the unit, which allows for quick transfer of information directly into the patient's electronic records.

Included with the autorefractor are a carrying case, a lithium ion battery which has a life of 3 hours of continuous use, a charging base for the battery, and a small, the portable printer mentioned previously, which contains paper tape for convenient printing at any location. The battery is charged using an AC outlet.

Autorefractors are devices which have been present in a variety of optometric and ophthalmologic practices for decades. While few, if any, practitioners will prescribe directly from an autorefractor, there is little doubt that they offer numerous advantages in a clinical setting. They offer an objective analysis of the patient's refractive error and, depending upon the skill of the clinician, the results may be more accurate, consistent, and more quickly obtained than with retinoscopy. Because of its ease of use, autorefraction may also be delegated to a technician or other member of the office staff. (Numerous studies have been performed in order to evaluate the various makes and models of stationary autorefractors on the market, some of which are detailed in sources 1-5.)

While the basic science behind these instruments has remained relatively constant, technology has allowed these devices to become much smaller and more portable. Recent years have seen the advent of handheld autorefractors, which allow the practitioner the aforementioned benefits of autorefraction in situations where this procedure was previously very difficult, if not impossible, to perform. Such situations include younger patients, disabled and/or bedridden patients, and patients seen out of the clinic on screenings. An additional benefit of the Welch Allyn Suresight autorefractor is its relatively low cost. At the time this research was performed, the cost of the instrument was less than half the price of its larger table-top counterparts, and in some instances, could qualify the practitioner for a tax credit through the Americans with Disabilities Act.

There exists in both optometric and ophthalmologic literature a large amount of research dedicated to the evaluation of various autorefractors. While most of these studies are devoted to the comparison of these devices to other methods of obtaining a refraction (such as subjective refraction and/or retinoscopy), some research exists which compares these devices to one another. However, due to the fact that handheld autorefractors are still relatively new devices, little research has been performed dedicated to the comparison of these devices to table-mounted, stationary autorefractors, or to other refraction techniques. Such research would be of value because of the many advantages offered by these smaller devices over their larger counterparts and retinoscopy, which is often replaced by autorefraction in the exam sequence. The goal of this study is to evaluate the accuracy and precision of the Welch Allyn Suresight 14000 handheld autorefractor when using clinically relevant criteria.

METHOD

Ninety-two subjects took part in this study, but the results from eight individuals were discarded due to a failure to meet the selection criteria. (Subjects with amblyopia, ocular pathology, or refractive surgery were excluded.) Of the eighty-four subjects used in the study, 52 were male and 32 were female. The age of the subjects ranged from 21 to 39 years with a mean of 26. For convenience, optometry students at Pacific University were used as the subjects. (Informed consent was obtained from each subject in accordance with the protocol established by the institutional review board.) The refractive errors ranged from +1.25 D to –6.25 D of sphere power with up to 2.00 D of minus cylinder power (see Tables 1 and 2 for a complete breakdown of refractive errors). The subjects were refracted with the Welch Allyn Suresight handheld autorefractor, the Canon RK-5 stationary autorefractor, static retinoscopy, and a subjective refraction. The data from the right eyes of eighty-two subjects and from two subject's left eyes were collected. (The two participants whose left eyes were measured had dilated right eyes at the time of the study due to requirements in a laboratory course.)

The refractive error was measured first with the Suresight handheld autorefractor. All autorefractor measurements (both handheld and static) were taken in the same vision exam room with the same illumination for each subject. This ensured that conditions were identical for all autorefractor comparisons. Each individual was seated in an exam chair and instructed to hold their head straight and vertically aligned. Care was also taken to ensure that the researchers held the handheld autorefractor correctly for accurate axis readings. The patient was instructed to look in the circle of green lights, where a red alignment light would appear. The examiner lined up the refractor using the viewfinder and listening to the beep variations. Once the data for each measurement was obtained, it was transferred to a data sheet if the confidence rating was 6 or higher. (Any results with a rating under 6 were discarded and the procedure was repeated.) Four measurements were obtained for each subject and the results for sphere, cylinder, and axis were averaged to obtain one final value. Alignment was ensured with each measurement.

Following the data collection with the handheld device, the subjects were then seated behind the Canon RK-5 and it was ensured that the participant's chin and forehead were correctly placed in the rest. Again, four measurements were obtained for each subject and the results of each were transposed by hand onto a data collection sheet. The instrument was aligned and focused properly between each measurement, and the sphere, cylinder, and axis results obtained via this method were averaged to obtain a final value.

Next, the subject was taken to an adjacent exam lane where a second examiner performed static retinoscopy, a tentative subjective sphere value, Jackson cross cylinder, and a monocular subjective best visual acuity (MSBVA) test. Care was taken to ensure that the patient was seated with the phoropter positioned to have the same vertex distance for each subject and all procedures were performed in accordance with the protocol taught at Pacific University College of Optometry using pre-scripted directions for the subjects. In order to assure complete objectivity, autorefractor values were concealed from the examiner performing retinoscopy and MSBVA. Retinoscopy and MSBVA values were recorded for each participant.

RESULTS

An analysis of variance (ANOVA) with Scheffe F-test at 90% level of significance and linear regression were performed in order to determine the relationship between the objective and subjective data, as well as between the two autorefractors. The averages of all four data points for each instrument were used for analysis.

Precision Repeatability of the two instruments was determined on a test-retest basis and both the Canon and the Suresight showed good internal presicion on the sphere and cylinder values. No significant differences were found between any of the four trials for either of the autorefractors. The standard errors of the four spherical and cylinder measurements taken using each of the autorefractors is provided in Table 3. This information demonstrates the variability of refractive errors as measured by each technique. In addition, the coefficient of repeatability (COR) was determined for each autorefractor by taking the average difference between four sets of measures, computing the standard deviation of this average difference, and multiplying by a factor of 2. This provides the 95% confidence interval for within-subject change across repeated measures. For the Suresight the COR was 0.414, and for the Canon the COR was 0.377. Thus, for both instruments, 95% of repeated measures on a single subject will be within approximately 0.4 D spherical equivalent; a change in spherical equivalent >0.4 D would be considered a significant change over time.

Table 4 illustrates whether refraction comparisons had a significant difference from each other as determined by the Scheffe F-test. The data demonstrates that no significant difference exists when comparing the sphere values obtained using all methods. When comparing the cylinder powers, the only significant difference was found to exist when comparing retinoscopy and subjective refraction. When only considering cylinder powers over one diopter, no significant difference was found between any of the cylinder data.

In order to further analyze the results obtained using each of the three methods, the average spherical equivalents were compared against each other to determine if any significant differences were present. These results are also included in Table 4 and illustrate that no significant differences exist.

Canon RK-5 Sphere vs. Retinoscopy Sphere When comparing the sphere values obtained using the Canon tabletop autorefractor to those observed with retinoscopy, we find that 73% are within 0.50 D, 17% are between 0.62 and 1.12 D, 7% show a difference of between 1.12 and 1.62 D, and the remaining 3% demonstrated a spherical power difference of greater than 1.75 D, including 2 subjects which had spherical values from the Canon RK-5 which differed by 2.75 D from the retinoscopy sphere. When we disregard the subjects with smaller amounts of subjective spherical refractive error (less than 3 diopters), the Canon provided 76% of subjects with spherical values within 0.50 D of their retinoscopy values and an additional 6% had differences between 0.62 and 1.12 D. Twelve percent of the Canon values were between 1.12 and 1.62 D of retinoscopy, and the remaining 6% had a difference of 2.75 D (n=33).

Suresight Sphere vs. Retinoscopy Sphere In analyzing the sphere values provided by the Suresight and comparing them to values obtained using retinoscopy, it is observed that approximately 60% of the Suresight results are within 0.50 D of the retinoscopy values, while 23% were between 0.62 and 1.12 D, 15% were between 1.12 and 2.12 D, and 2% have a difference of 3.00 D or more. When only considering subjects with refractive errors of 3 diopters or more (n=33), 55% of Suresight sphere values were within 0.50 D of their corresponding retinoscopic findings, 27% showed differences between 0.62 D and 1.12 D, 12% of Suresight readings deviated between 1.12 and 2.00 D from retinoscopy, and 6% of subjects showed differences of over 2.00 D. (A detailed comparison of all results obtained using the Suresight to the refractions obtained using the other methods which were included in this study is contained in Tables 5-8.)

Canon RK-5 Sphere vs. Subjective Sphere Comparison of sphere values provided by the Canon tabletop autorefractor to the results from subjective refraction shows that 89% of all subject's sphere values were within 0.50 D of their corresponding subjective values. An additional 7% had spherical refractions which differed by 0.75 D, one subject's (1%) sphere value differed by 1.50 D, and two subjects (2%) had spherical refractive errors obtained using the Canon RK-5 which differed by 3.50 D from the subjective values. When only those subjects with 3.00 D or more of spherical refractive error were considered (n=33), the Canon provided spherical values within 0.50 D of subjective sphere in 82% of our subjects, while 12% of subjects had results with a deviation of 0.75 D from their subjective values, one subject (3%) had a difference of 1.50 D, and the Canon only produced a difference of 3.50 D in one subject (3%). An interesting item of note is that, when compared to subjective refraction, the Canon RK-5 tended to slightly overminus our subjects, with an average difference of
-0.14 D.

Suresight Sphere vs. Subjective Sphere The comparison of the average sphere values obtained with the Suresight with the subjective sphere values reveals that 55% of the Suresight's readings were within 0.50 D of subjective findings, while 29% were between 0.62 and 1.12 D, 12% were between 1.12 and 2.12 D, and 5% had a discrepancy of 2.50 D or more. Interestingly, when disregarding all spherical values of less than 3.00 diopters (n=33), the Suresight still produces a difference of 0.50 D or less in 55% of subjects, 30% of subjects were provided with values between 0.62 and 1.12 D from their subjective values, and the remaining 15% of subjects had a difference in sphere values of between 1.12 and 1.62 D. As with the Canon, the Suresight had a tendency to overminus subjects, with the average difference being a more clinically significant -0.21 D from subjective sphere values.

Canon RK-5 Cylinder Power vs. Retinoscopy Cylinder Power When only considering subjects with 1.00 D or more of astigmatism (n=15, as one subject with over 1 D of astigmatism was not found to have any cylinder refractive error with retinoscopy), 56% of subjects had a difference of cylinder power of 0.25 D or less when comparing the Canon and retinoscopy, 31% had differences between 0.62 and 0.87 D, and the remaining approximately 12% had cylinder power differences of 1.00 or 1.25 D.

Suresight Cylinder Power vs. Retinoscopy Cylinder Power Again, when only considering those subjects with cylinder powers of 1.00 diopter or more (n=15), the Suresight provided cylinder values within 0.25 diopters of retinoscopy in 38% of subjects, while all of the remaining subjects had a difference between 0.62 and 0.87 D.

Canon RK-5 Cylinder Power vs. Subjective Cylinder Power When comparing the results for cylinder power obtained using the Canon RK-5 to those obtained using a subjective refraction in subjects with over 0.75 D of cylinder (n=16), it was found that an impressive 81% had values with 0.25 D or less difference. The remaining 19% had a difference between the two values of 0.50 or 0.75 D.

Suresight Cylinder Power vs. Subjective Cylinder Power In subjects with 1.00 diopters or more of astigmatism (n=16), 48% had cylinder power differences of 0.25 D or less when comparing the Suresight to subjective refraction. A difference between the two methods of 0.62 to 0.87 D was found in the final 57%.

Canon RK-5 Cylinder Axis vs. Retinoscopy Cylinder Axis In comparing cylinder axis placement in subjects with 1.00 diopters or more of cylinder refractive error (n=15), the Canon RK-5 and retinoscopy provided results which differed by 0 to 5 degrees in 31% of subjects. An additional 31% of subjects had differences between the two methods of 6 to 10 degrees, 19% more had differences of 11 to 15 degrees, and one subject (7%) had a difference in cylinder axis placement of between 16 and 20 degrees. The final subject (7%) had a difference of 32 degrees.

Suresight Cyliner Axis vs. Retinoscopy Cylinder Axis In subjects with over one diopter of astigmatism (n=15) the Suresight differed from retinoscopy in its placement of cylinder axis by zero to 5 degrees in 31% of our subjects. A larger difference of 6 to 10 degrees was noted in an additional 31%, an additional 13% had differences which lied between 11 and 15 degrees, 13% more had an axis placement which differed by 16 to 20 degrees between the two methods, and the final subject (7%) had an axis difference of 30 degrees.

Canon RK-5 Cylinder Axis vs. Subjective Cylinder Axis When only considering subjects with 1.00 D or more cylinder refractive error (n=16), the Canon RK-5 placed the axis within 5 degrees of the subjective axis placement in 100% of our subjects.

Suresight Cylinder Axis vs. Subjective Cylinder Axis The Suresight was considerably less accurate than the Canon RK-5 in its placement of the cylinder axis when compared to subjective refraction. The difference between these two methods in subjects with 1.00 D or more astigmatism (n=16) was within 5 degrees in 44% of subjects, and 13% of subjects had differences of 6 to 10 degrees when comparing the two methods. An additional 31% of subjects differed by 11 to 15 degrees, and one subject (7%) had an axis placement difference of 21 to 25 degrees. The final subject (7%) differed in axis placement by between 41 and 45 degrees between the two methods.

Linear Regression Results In order to assess how well the objective measures predicted subjective refraction, the spherical equivalents of the subjective findings were plotted against the objective findings for each method. Results for the Canon RK-5, shown in Chart 1, demonstrate that the objective measures provide an accurate predicition of subjective refraction, accounting for 91% of the variability in subjective findings (r^2=0.91). The minimal intercept (0.026) and slope of this relationship (.92) indicate that this prediction differs by a constant factor (0.92), leading to slightly greater dioptric error at higher refractive errors. A similar regression comparing subjective refraction to retinoscopy is detailed in Chart 2. This chart also demonstrates that the objective measure (retinoscopy) provides an accurate prediction of the subjective value (r^2=0.93). Here the slope is closer to 1/1 (0.97), while the intercept (0.15) indicates that retinonoscopy tends to overestimate minus and underestimate plus by a small amount, with the effect increasing at higher degrees of myopia. A final regression was performed after plotting subjective refraction against the spherical equivalents of the results obtained with the Suresight. As seen in Chart 3, the prediction from Suresight was somewhat less accurate, accounting for 77% of the variability in subjective refraction (r^2=0.77). To demonstrate the predictions obtained from the regression analysis, Table 9 shows the subjective refraction (i.e., actual refraction), predicted from the regression equation derived for each objective method. As shown, both the Canon RK-5 and retinoscopy provide accurate measures of subjective refraction at lower degrees of ametropia, but tend to be somewhat more discrepant at higher levels of myopia. In comparison, the prediction from Suresight data shows greater error for low to moderate ametropia, but tends to be more accurate for higher myopia. It should be noted, however, predictability was more variable for Suresight; and the model is based on a limited number of higher refractive errors.

DISCUSSION

Several past studies have been conducted comparing the results obtained using various static autorefractors to those obtained via retinoscopy. Two such studies, conducted on children, showed that the Nidek ARK-900 and HARK autorefractors were comparable or superior to retinoscopy in producing best possible visual accuities.[1,2] Another similar project performed on adults showed similar results, as the Canon Autoref R-1 and Dioptron II devices were shown to have results comparable to those obtained using autorefraction.[3] However, past research also indicates that some devices are more accurate than others, as an older autorefractor, the Dioptron, has been demonstrated to be less accurate that retinoscopy in determining the cylinder power.[4] Additional research, performed by Zadnik, et al, was performed in an effort to determine the repeatability of several methods of obtaining ocular measurements, including refractive error. The results show that autorefraction, in combination with cycloplegia, is the most reliable measure of refractive error. This study also revealed that cycloplegic retinoscopy was the least reliable method of obtaining refractive error measurements.[5] Zadnik's results are further confirmed by Walline, et al, who performed a study comparing the repeatability and validity of various methods of obtaining astigmatism measurements and determined that cycloplegic autorefraction was the most reliable source for obtaining this data and cycloplegic retinoscopy was the least reliable method.[6]

Our own results indicate that, when compared to the subjective refraction, retinoscopy tends to overminus the sphere value by an average of 0.11 D and underestimate the cylinder by 0.17 D, when considering only subjects with 1.00 D of cylinder or more. The retinoscopic sphere findings contradict past research which has indicated that in young eyes (such as those belonging to the subjects in our study), retinoscopy tends to give results which are approximately 0.3 to 0.4 diopters more plus than subjective refraction.[7] However, it is also well-known that retinoscopy is a skill with a very definite learning curve. Thus, a source of possible error arises due to the lack of experience of the researchers, who are themselves 3rd year optometry students. In fact, a past Pacific University thesis project has shown that there is typically a considerable amount of improvement in retinoscopy accuracy between the 3rd and 4th years of optometry school.[8]

As has been discussed previously, research has indicated that traditional static autorefraction tends to be almost as accurate as retinoscopy as a method of obtaining an objective refraction. Due to the rather recent advent of the technology required to create a small handheld autorefractor, relatively little research exists to demonstrate the accuracy of these devices. Most past research has focused on the Nikon Retionomax handheld autorefractor. In one such study conducted at the Pacific University College of Optometry, this device was shown to have reasonable accuracy and precision but, when compared to a subjective refraction, was not as accurate as a static tabletop autorefractor (the Nidek AR-1100). This same research showed that the Retinomax tended to give better results with higher refractive errors.[9] Further investigation has supported the conclusion that the Retinomax provides at least reasonable accuracy. Cordonnier and Kallay stated that they felt that this instrument had "definite" usefulness in the refractive screening of children.[10] Harvey, et al support the usefulness of the Retionomax in the examination of children.[11] However, despite the apparent usefulness of this earlier handheld autorefractor in younger patients, at least one group of researcher found that in their study the device tended to overminus children, sometimes by as much as 2 diopters and that often cycloplegia was necessary to obtain reasonable results.[12] Such research in children is very insightful, as this is the group of patients that the manufacturers of handheld autorefractors claim are best served by these relatively new devices.

Because of the relatively recent release of the Suresight handheld autorefractor, very little research has been conducted using this instrument. The studies which have been performed have been performed on children. One set of researchers concluded that the Suresight was less accurate than conventional autorefractors and that cycloplegia was often necessary to obtain acceptable results.[13] Another study demonstrated that the repeatability of the readings was poor, especially for the measurement of the spherical refractive error. (As many as 17% of subjects used in the study had a spherical value which differed by 1 diopter or more between measurements.)[14] However, despite the apparent shortcomings of the Suresight, both of the aforementioned studies concluded that it had a definite usefulness for the refraction of children and uncooperative or disabled patients.

Our own findings indicate that, in contrast with the Retinomax (which was shown to have more accuracy in higher refractive errors), the Suresight appears to have equal accuracy regardless of refractive error. (As noted previously, our results show that the Suresight gives spherical readings that are within 0.50 diopters of the subjective value in 55% of subjects with refractive errors greater or equal to 3 diopters and 55% of subjects with lower refractive errors.) As seen by our results, when compared to subjective refraction, the Suresight appears to be less accurate in obtaining both sphere and cylinder power than the Canon RK-5 and is much less accurate with regards to axis placement compared to its tabletop counterpart in subjects with greater than 0.75 diopters of cylinder refractive error. When compared to retinoscopy, the Suresight also appears to be somewhat less accurate in obtaining spherical values, but approximately equally dependable with respect to cylinder power and axis (again, in subjects with over 0.75 diopters of astigmatism).

As with any type of research using statistical comparisons to reach its conclusions, the methods used in this study are subject to debate. First of all, in our analysis of cylindrical power and axis location, all cylinder values less than one diopter are excluded. This is done due to the fact that axis placement with such a small amount of cylinder is very difficult, especially with retinoscopy. A second source of difficulty is the fact that all of our analysis is done considering the spherical value, the cylinder value, and the axis location as separate entities. Any clinician is aware that these three values are, by no means, independent of each other. The most feasible method of overcoming this obstacle has been presented by McCaghrey and Matthews, who propose the use of subjective over-refraction of the autorefractor values to determine exactly how much under or overcorrection is provided by each device.[15] Despite the apparent simplicity of this proposal, this method does not allow for a clear-cut statistical comparison of results. In addition, if the cylinder axes of the two measurements being compared do not correspond, complicated cross-cylinder calculations must be performed. While cross-cylinder calculations do provide the highest level of accuracy when comparing two refractions with varying cylindrical axes, they are most useful with higher amounts of astigmatism. In our study, none of our subjects had more than a moderate amount of astigmatism and thus, it was concluded that our results would not be significantly altered by the use cross-cylinder calculations.

CONCLUSION

The Welch Allyn Suresight handheld autorefractor, when compared to a subjective refraction, showed moderate precision and an acceptable amount of accuracy, which improved at higher refractive errors. It tended to provide an accuracy nearly equal to retinoscopy performed by third-year optometry students, but was somewhat less accurate than the Canon RK-5, especially with regards to cylinder axis placement. All objective means of obtaining refractions provided results which were more minus on average than subjective spherical measurements, possibly due to a poor control of accommodation. This was especially evident on the Suresight, which has the least amount of accommodative control of all objective methods used in this study. This also may explain the fact why past research has indicated that the Suresight's findings are more repeatable when patients are cyclopleged. However, in spite of its shortcomings, the Suresight provides a method to obtain easy and reasonably accurate refractions for all patients, including children and other patients who would otherwise provide challenges to the practitioner desiring an objective refraction as part of his or her examination.

Table 1:
Subject Sphere Distribution

Sphere Amount	Frequency	Percentage
+1.25	1	1.2
+1.00	2	2.4
+0.75	3	3.6
+0.50	2	2.4
+0.25	7	8.3
0.00	5	6
-0.25	7	8.3
-0.50	5	6
-0.75	0	0
-1.00	6	7.1
-1.25	1	1.2
-1.50	3	3.6
-1.75	3	3.6
-2.00	1	1.2
-2.25	3	3.6
-2.50	3	3.6
-2.75	1	1.2
-3.00	3	3.6
-3.25	2	2.4
-3.50	4	4.8
-3.75	3	3.6
-4.00	6	7.1
-4.25	3	3.6
-4.50	3	3.6
-4.75	1	1.2
-5.00	1	1.2
-5.25	1	1.2
-5.50	2	2.4
-5.75	1	1.2
-6.00	0	0
-6.25	1	1.2
Total	84	100

Table 2:
Subject Cylinder Distribution

Cylinder Amount	Frequency	Percentage
0.00	36	42.9
-0.25	12	14.3
-0.50	11	13.1
-0.75	9	10.7
-1.00	6	7.1
-1.25	5	6
-1.50	3	3.6
-1.75	1	1.2
-2.00	1	1.2
Total	84	100

Table 3:
Precision of Autorefractors
(Variability of instruments from trial to trial)

	Suresight Sphere (D)	Suresight Cylinder (D)	Canon Sphere (D)	Canon Cylinder (D)
Standard Error	0.176	0.038	0.223	0.053

Table 4:
Refraction Comparison by Significance (ANOVA)

Sphere	Suresight	Canon
Canon	N	
Retinoscopy	N	N
Subjective	N	N
Cylinder		
Canon	N	
Retinoscopy	N	N
Subjective	N	N
Spherical Equivalent		
Canon	N	
Retinoscopy	N	N
Subjective	N	N

N = Not significantly different at 90% by Scheffe F-Test

Table 5:
Subjective Sphere Power Compared to Retinoscopy, Suresight, and Canon Autorefractor
(n=84)

Difference from Subjective (Diopters)	Retinoscopy N (%)	Suresight N (%)	Canon N (%)
0.00	13 (15.5%)	11 (13.1%)	27 (32.1%)
0.25	27 (32.1%)	17 (30.2%)	33 (39.3%)
0.50	22 (26.2%)	18 (21.4%)	15 (17.9%)
0.75	11 (13.1%)	14 (16.7%)	6 (7.1%)
1.00	7 (8.3%)	10 (11.9%)	0
1.25	2 (2.4%)	3 (3.6%)	0
1.50	1 (1.2%)	3 (3.6%)	1 (1.2%)
1.75	0	4 (4.8%)	0
2.00	0	0	0
2.25	0	0	0
2.50	0	2 (2.4%)	0
2.75	0	1 (1.2%)	0
3.00	0	0	2 (2.4%)
3.75	0	1 (1.2%)	0
4.00	0	0	0
5.00	1 (1.2%)	1 (1.2%)	0
Total	84 (100%)	84 (100%)	84 (100%)

Table 6:
Subjective Cylinder Power Compared to Retinoscopy, Suresight, and Canon Autorefractor for all Cylinder Values
(n=84)

Difference from Subjective (Diopters)	Retinoscopy N (%)	Suresight N (%)	Canon N (%)
0.00	20 (23.8%)	7 (8.3%)	35 (41.7%)
0.25	25 (29.8%)	39 (46.4%)	27 (32.1%)
0.50	21 (25.0%)	25 (29.8%)	20 (23.8%)
0.75	7 (8.3%)	11 (13.1%)	2 (2.4%)
1.00	3 (3.6%)	2 (2.4%)	0
1.25	2 (2.4%)	0	0
1.50	5 (6.0%)	0	0
1.75	1 (1.2%)	0	0
Total	84 (100%)	84 (100%)	84 (100%)

Table 7:
Subjective Cylinder Power Compared to Retinoscopy, Suresight, and Canon Autorefractor for Cylinder Values Over 0.75 D as measured by subjective refraction (n=16)

Difference from Subjective (Diopters)	Retinoscopy N (%)	Suresight N (%)	Canon N (%)
0.00	1 (6.3%)	3 (18.8%)	7 (43.8%)
0.25	6 (37.5%)	4 (25.0%)	6 (37.5%)
0.50	5 (31.3%)	5 (31.3%)	2 (12.5%)
0.75 or greater	4 (25.0%)	4 (25.0%)	1 (6.3%)
Total	16 (100.1%)	16 (100.1%)	16 (100.2%)

Table 8:
Subjective Cylinder Axis Compared to Retinoscopy, Suresight, and Canon Autorefractor for Cylinder Values over 0.75 D as measured by subjective refraction (n=16)

Difference from Subjective (in degrees)	Retinoscopy N (%)	Suresight N (%)	Canon N (%)
0-5	5 (33.3%)	7 (43.8%)	16 (100%)
6-10	5 (33.3%)	2 (12.5%)	0
11-15	2 (13.3%)	5 (31.3%)	0
16-20	2 (13.3%)	0	0
21-25	0	1 (6.3%)	0
26-30	1 (6.7%)	0	0
31-35	0	0	0
36-40	0	0	0
41-45	0	1 (6.3%)	0
46-50	0	0	0
51-55	1 (6.7%)	0	0
Total	15* (100%)	16 (100%)	16 (100%)

* One subject with over 0.75 D of cylinder as found by subjective refraction was determined to have no cylinder when using retinoscopy. Hence, all comparisons of retinoscopy have one fewer subject than in comparisons of other methods.

Table 9:
Predicted Subjective Results Based On Objective Measures

	Predicted Subjective Measures		
Autorefractor Measure	Suresight	Canon	Retinoscopy
1	1.6501	0.9473	1.1208
0.5	1.1036	0.48665	0.634
-0.5	0.0106	-0.43465	-0.3396
-1	-0.5359	-0.8953	-0.8264
-1.5	-1.0824	-1.35595	-1.3132
-2	-1.6289	-1.8166	-1.8
-2.5	-2.1754	-2.27725	-2.2868
-3	-2.7219	-2.7379	-2.7736
-3.5	-3.2684	-3.19855	-3.2604
-4	-3.8149	-3.6592	-3.7472
-4.5	-4.3614	-4.11985	-4.234
-5	-4.9079	-4.5805	-4.7208
-5.5	-5.4544	-5.04115	-5.2076
-6	-6.0009	-5.5018	-5.6944

Chart 1:
Subjective Spherical Equivalent vs. Canon RK-5 Spherical Equivalent

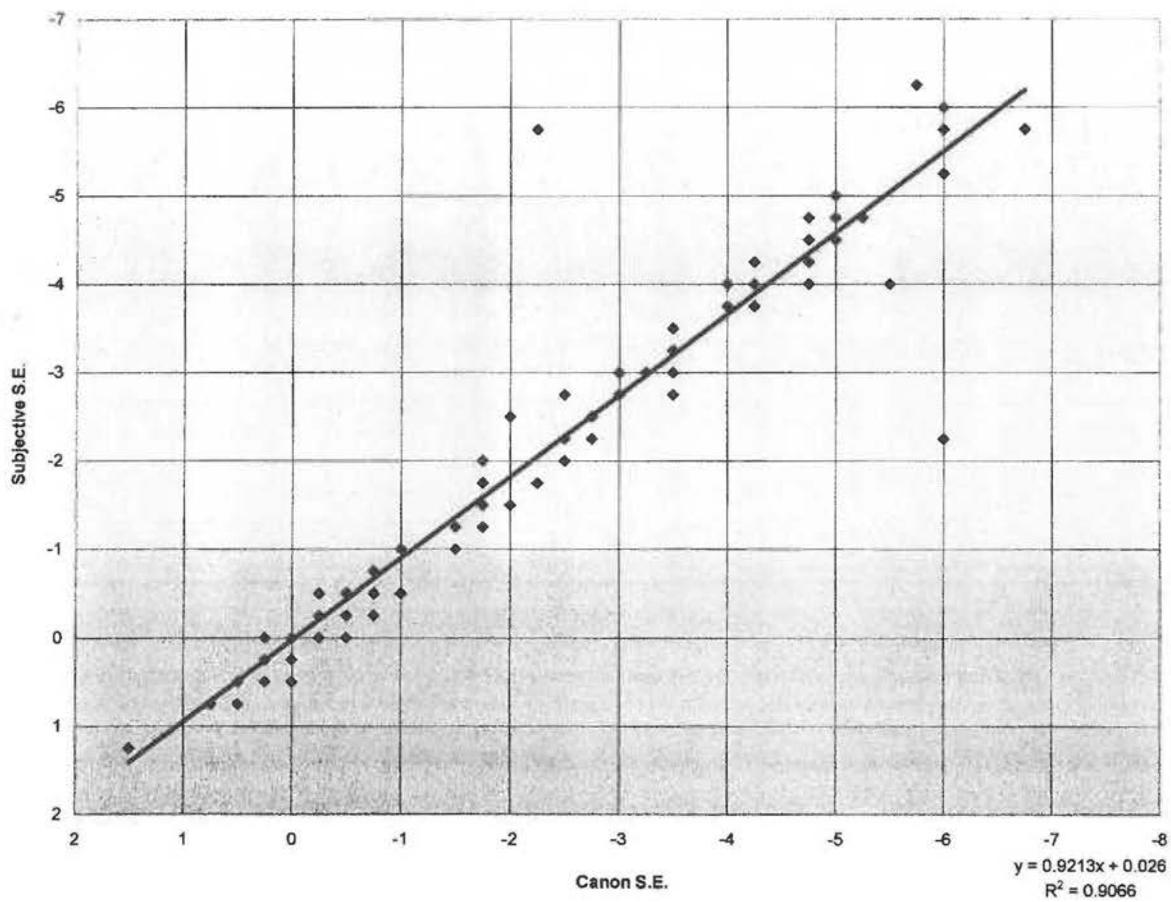


Chart 2:
Subjective Spherical Equivalent vs. Retinoscopy Spherical Equivalent

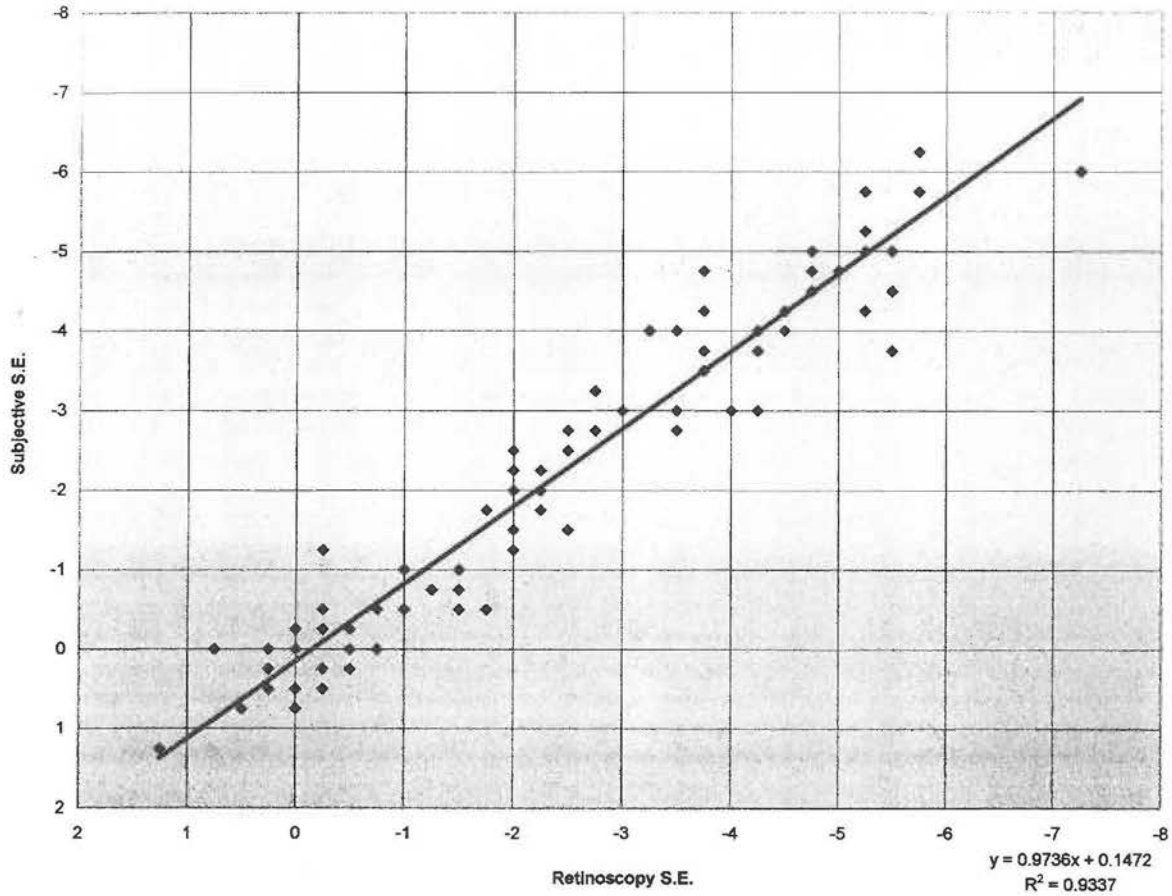
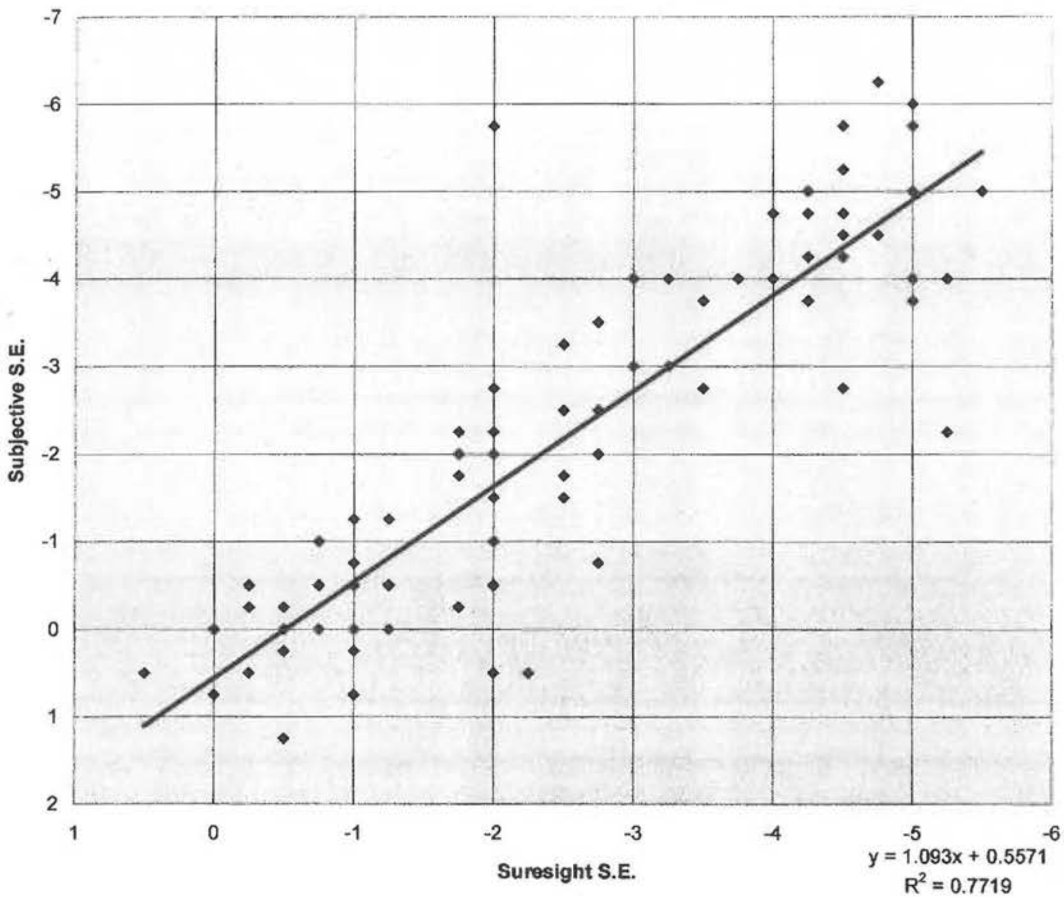


Chart 3:
Subjective Spherical Equivalent vs. Suresight Spherical Equivalent



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