Evaluation of the measurement of refractive error by the PowerRefractor: a remote, continuous and binocular measurement system of oculomotor function

O A Hunt, J S Wolffsohn, B Gilmartin

Background/aim: The technique of photorefractometry is unique in being able to measure the dynamics of the oculomotor system (ocular accommodation, vergence, and pupil size) remotely (working distance typically 1 metre) and objectively in both eyes simultaneously. The aim of this study was to evaluate clinically the measurement of refractive error by a recent commercial photorefractive device, the PowerRefractor (PlusOptiX, Germany).

Method: The validity and repeatability of the PowerRefractor was compared to: subjective (non-cycloplegic) refraction on 100 adult subjects (mean age 23.8 (SD 5.7) years) and objective autorefraction (Shin-Nippon SRW-5000, Japan) on 150 subjects (20.1 (4.2) years). Repeatability was assessed by examining the differences between autorefractor readings taken from each eye and by re-measuring the objective prescription of 100 eyes at a subsequent session.

Results: On average the PowerRefractor prescription was not significantly different from the subjective refraction, although quite variable (difference $\pm 0.05$ (0.63) D, $p = 0.41$) and more negative than the SRW-5000 prescription (by $-0.20$ (0.72) D, $p < 0.001$). There was no significant bias in the accuracy of the instrument with regard to the type or magnitude of refractive error. The PowerRefractor was found to be repeatable over the prescription range of $-8.75$D to $+4.00$D (mean spherical equivalent) examined.

Conclusion: The PowerRefractor is a useful objective screening instrument and because of its remote and rapid measurement of both eyes simultaneously is able to assess the oculomotor response in a variety of unrestricted viewing conditions and patient types.

The oculomotor triad comprising ocular accommodation, vergence, and pupil size is essential to seeing a clear, single, luminance intensity controlled image of the outside world. Continuous measurement of the oculomotor system is needed to understand further conditions such as ocular neurological effects and their progression, the potential of multifocal intraocular lenses, and the efficacy of orthoptic training. Although many techniques have been devised to measure accommodation continuously over the past two decades, photorefractometry is unique in enabling the measurement of accommodation, vergence, and pupil size in both eyes simultaneously, objectively, remotely (typically the camera is placed 1 metre from the eyes) and continuously.

The PowerRefractor is the first commercially available instrument to use photorefractometry and allow continuous measurement of the oculomotor triad. The instrument is marketed principally as a vision screener, for the objective measurement of refractive error.

Choi and colleagues attempted to validate the PowerRefractor, but there were several limitations to their study: the PowerRefractor measures were compared in only 15 subjects with the patient’s previous spectacle prescription and not in a current full subjective refraction; subjective refraction was performed on 40 patients, but details of the refraction were not given and the subjects had a variety of ocular pathologies; the authors’ kindergarten study only compared the results with the Canon R-1 open field autorefractor; the intrasession repeatability was not assessed and intersession repeatability was only measured in the kindergarten group.

Three different techniques of photorefractometry have been described: orthogonal, isotropic, and eccentric but all work on the principal of analysing the vergence of reflected light rays returning to a camera after illuminating a point on the retina. The PowerRefractor uses the latter technique, with an infrared light source located on the edge of a mask, eccentric to the optical axis of the camera. If the eye is accurately focused at the camera distance, the infrared light reflected from the fundus is imaged in the camera plane as an even luminance over the entire pupil. However, if the eye is defocused myopically with respect to the camera, the light reflected from the fundus is focused in a plane between the eye and the camera and subsequently spread out in a cone, the angle of which depends on the amount of defocus. Because the mask covers part of the camera lens, only rays emanating from same part of the pupil are imaged. Conversely, for an eye focused hyperopically in respect of the camera, only rays emanating from the opposite part of the pupil will be illuminated. The resulting light gradient across the pupil is measured by the PowerRefractor in six meridians separated by 30° simultaneous to a pulse of infrared light emitting diodes (LEDs) mounted on a knife edge perpendicular to each meridian in turn. The gradient of each pair of opposite meridians is averaged to remove the effect of asymmetrical meridians and the spherocylindrical refraction calculated.

The aim of this study was to assess the validity and repeatability of the PowerRefractor to measure refractive error in non-cycloplegic adults to both subjective refraction and to a recently validated open field autorefractor, the Shin-Nippon SRW-5000.

Patients and methods
In all, 100 subjects (40 male and 60 female), with a mean age of 23.8 (SD 5.7) years (range from 18 to 45 years, median 22.0 years) participated in the study. Subjects with ocular
Evaluation of the PowerRefractor

A manner similar to that of retinoscopy the end point of subjective refraction as quickly as possible, in designed to assist ophthalmologists and optometrists to reach from the right eye were analysed. The bias between measures as the refractive error of the two eyes are related, only data from the right eye were analysed. The bias between measures was performed using paired two tailed t tests. Assessing the variance in the astigmatic component poses a problem in the conventional clinical notation. Therefore the sphere, cylinder, and axis component were converted into a vector representation for analysis: a spherical lens of power MSE (the mean spherical equivalent = sphere+(cylinder/2)); Jackson cross cylinder at axis 0° with power J0 (=-[cylinder/2] cos2 x axis); Jackson cross-cylinder at axis 45° with power J45 (=-[cylinder/2] sin2x axis).

RESULTS
The refractive error of the sample, as represented by the subjective refraction, ranged from −8.75 to +4.00D mean spherical equivalent (MSE mean = −1.44 (SD 2.44) D). The maximum amount of measured astigmatism was = 4.50DC.

Prescription component differences between the PowerRefractor and subjective or SRW-5000 autorefractor compared to subjective refraction are shown in Table 1. The mean difference in components measured by the PowerRefractor was in better agreement with non-cycloplegic subjective refraction than the SRW-5000 autorefractor, but were variable in both cases (Figs 1 and 2). The broken lines on the graphs (95% confidence interval) indicate the extent to which the PowerRefractor might over-read or under-read compared to the alternative methods examined (that is, the PowerRefractor might read as much as 1.28D above or 1.18D below subjective refraction for MSE).

There appears to be no bias in the accuracy of the PowerRefractor with the type or magnitude of refractive error (slope of regression line <0.05), although there are a few outlying values to the data, principally those with high myopia. Approximately 39% of PowerRefractor readings were within ±0.25D, and 67% within ±0.50D of the MSE as found by subjective refraction and 31% were within ±0.25D, and 57% within ±0.50D of the MSE as found by the SRW-5000 autorefractor (Fig 1B).

Table 2 shows the difference in the J0 and J45 component of patients’ refractions between subjective refraction, SRW-5000 autorefractor and PowerRefractor compared to the mean value. Approximately 50% of PowerRefractor measures were within ±0.25D and 74% within ±0.50D of the cylindrical component of the prescription found by subjective refraction and 49% were within ±0.25D and 81% within ±0.50D of the cylindrical component found by SRW-5000 autorefractor. The axis of the cylindrical component was less reliable than the spherical and cylindrical power components (Table 2). However, if only cylindrical components >0.75D are considered (as these are likely to have more than a 0.1 logMAR affect on distance visual acuity if significantly off axis), the accuracy of cylindrical axis calculated by the PowerRefractor is found to be improved.

Inter session repeatability (that is, the standard deviation of differences between five measures taken on one occasion)
was 0.050D for the spherical component, 0.062D for the cylindrical component 0.062D for the mean spherical equivalent, 0.036 for the $J_0$ and 0.029 for the $J_{45}$ component.

Table 3 presents the mean intrasession differences between the prescription components. These were found to be small, with the majority of the second visit prescriptions falling within plus or minus 0.50D of the initial measurement.

**DISCUSSION**

The ability of the PowerRefractor to measure continuously from a remote location, binocular parameters of the complete oculomotor triad, will prove to be of great value in optometric and ophthalmological research. Commercial photorefractive devices have been available for a number of years, but only for static measure of refractive error. For example the MTI photoscreener is used in preschool screening in the United States, but requires the Polaroid of the imaged pupil crescents to be measured individually by a trained observer. Schaeffel and Howland tried to digitise this process, but were limited by the processor speed at the time, the dead zone obscuring low prescriptions and the non-linearity of the brightness across the pupil. The TOMEY ViVA and PR2000 were found to have only reasonable accuracy up to $\pm 3.00$ D, which may be the result of using a single light source, resulting in a large dead zone and a non-linear intensity gradient versus refractive error. Linearity is improved by using LEDs at more than one eccentricity below the knife edge and by measuring the slope of the brightness profile across the pupil rather than the height of the pupil crescents.

Although on average the PowerRefractor prescription was similar to that of subjective refraction, the range of differences was large (up to 3.5D), with 95% of readings
within \(\pm 1.12\) D (Fig 2). This was particularly the case with myopic prescriptions over \(-4.0\) D, confirming the stated accuracy range of the PowerRefractor by Choi and colleagues.\(^2\) However, the discrepancy between the PowerRefractor prescription and subjective refraction within this range could still be up to 2.5 D. Undercorrecting myopia by such a degree would severely reduce a patient’s visual acuity and in young children could lead to impaired visual development. Two subjects with a prescription of greater than \(-10.0\) D were assessed outside of the study, for whom the PowerRefractor indicated a prescription of only \(-3.0\) to \(-4.0\) D. Compared to the Shin-Nippon SRW-5000 autorefractor, the PowerRefractor prescription was more negative and again had a wide range of differences. Both autorefractors measure refractive error using imaging analysis techniques of infrared light reflected from the fundus, although the PowerRefractor measures the light gradient and the SRW-5000 the reflected image size. Compared to previously validated open field autorefractors (for example, the Canon R-1 and Shin-Nippon SRW5000) the PowerRefractor is, on average, just as accurate, but approximately 24–42% more variable.\(^1\)\(^0\) Inter-session and intra-session repeatability of the PowerRefractor was found to be small and was similar to previously validated open field autorefractors.\(^1\)\(^0\)\(^2\)\(^0\) This would indicate that the variability is due to the lack of individual calibration, the poor accommodative stimulus of the camera head LEDs, and perhaps the linear range of the change in light gradient across the pupil with refractive error,\(^1\)\(^9\) rather than stability of the imaging technique. An emmetrope focusing accurately at the camera distance should have a uniformly illuminated pupil. However, chromatic aberration, lead of accommodation, and in children small eye artefacts, all combine to produce focusing error and hence a light gradient across the pupil. As a slope change of \(+0.50\) D translates to approximately 1.0 D, small changes in slope can have a significant effect of apparent refraction. In addition, as the camera head is closer than optical infinity, \(\pm 1.0\) D myope, emmetrope and pre-presbyopic hypermetrope could all appear to have the same refractive error when focusing on the camera head LEDs at 1 metre. A more suitable target would be a non-accommodative distant target (such as a spot of light) with \(+1.0\) D added to the internally generated prescription.

![Figure 3](https://www.bjophthalmol.com)

**Figure 3** (A) Accommodative stimulus response curve for an emmetropic subject measured with the PowerRefractor and SRW-5000; (B) changes in the oculomotor response triad for the same subject binocularly viewing a target oscillating at 0.1 Hz between 10 cm and 50 cm.

<table>
<thead>
<tr>
<th>Difference in refractive component of the PowerRefractor found between different sessions</th>
<th>MSE</th>
<th>(\lambda_0)</th>
<th>(\lambda_{15})</th>
<th>Sphere</th>
<th>Cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean difference</td>
<td>0.06</td>
<td>(-0.001)</td>
<td>0.003</td>
<td>0.07</td>
<td>(-0.01)</td>
</tr>
<tr>
<td>SD of differences</td>
<td>0.36</td>
<td>0.11</td>
<td>0.05</td>
<td>0.36</td>
<td>0.12</td>
</tr>
<tr>
<td>Within (\pm 0.25) D (%)</td>
<td>84</td>
<td>(-)</td>
<td>(-)</td>
<td>86</td>
<td>92</td>
</tr>
<tr>
<td>Within (\pm 0.50) D (%)</td>
<td>96</td>
<td>(-)</td>
<td>(-)</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>Within (\pm 0.75) D (%)</td>
<td>98</td>
<td>(-)</td>
<td>(-)</td>
<td>98</td>
<td>100</td>
</tr>
</tbody>
</table>

In conclusion, the PowerRefractor is a practical and effective autorefractor over the range of refractive error \((-8.75\) to \(+4.00\) D) and age (18–45 years) assessed. It is likely to have a particular use in the screening of children and patients unable to give a subjective response. The variability, particularly with high myopia is, however, of some concern, with potential under correction of over 1 D in \(-7\)% of cases. The instrument will also be useful in research as it is able to measure remotely accommodation, pupil size, and gaze direction in both eyes simultaneously at 25 Hz, providing objective measures of the oculomotor system while subjects binocularly view a natural scene in an unenclosed and unrestricted environment.
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