Clinical evaluation of the Shin-Nippon SRW-5000 autorefractor in adults: an update

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Keywords: Shin-Nippon SRW-5000, Grand Seiko, open-view autorefractor, accommodation measurement

Abstract

Purpose: The Shin-Nippon SRW-5000 is an open view autorefractor that superseded the Canon R-1 autorefractor in the mid-1990s and has been used widely in optometry and vision science laboratories. It has been used to measure refractive error, accommodation responses both statically and dynamically, off-axis refractive error, and adapted to measure pupil size. This paper presents an overview of the original 2001 clinical evaluation of the SRW-5000 in adults[1] and provides an update on the use and modification of the instrument since the original publication.

Recent findings: The SRW-5000 instrument, and the family of devices which followed, have shown excellent validity, repeatability, and utility in clinical and research settings. The instruments have also shown great potential for increased research functionality following a number of modifications.

Summary: The SRW-5000 and its derivatives have been, and continue to be, of significant importance in our drive to understand myopia progression, myopia control techniques, and oculomotor function in human vision.

Introduction

Prior to the arrival of the Shin-Nippon SRW-5000 in the mid 1990s many researchers in the field of accommodation and refractive error research were using the Canon Autoref R-1 autorefractor. The device, launched in 1981, was shown to be effective in its clinical application [2] but its open-view design provided researchers with a hugely versatile system for the measurement accommodation responses. Experimental participants were able to view objects in free-space or targets located within a Badal lens arrangement: the former to provide, for example, measurements of accommodative response gradients [3], synkinesis of accommodative and vergence adaptation [4] and peripheral refraction [5]; the latter to allow isolation of the blur-driven accommodation stimulus [6]. In addition, the infra-red measurement system facilitated examination of open-loop accommodation responses to investigate, for example, tonic accommodation [7] and the influence of visual tasks on adaptation of tonic accommodation [8]. A particularly valuable application of the binocular open-field viewing arrangement was the ability to measure reliably closed-loop within-task accommodative adaptation using the temporal characteristics of regression of accommodation to a post-task open-loop tonic resting position [9]. In addition, the conversion of the Canon R-1 to continuous recording of accommodation responses [10] provided new insights into the nature and significance of accommodative microfluctuations in sustained near vision [11].

Given the impressive experimental portfolio of the Canon R-1 trepidation among researchers during the 1990s concerning its inevitable demise was alleviated by the introduction of the Shin-Nippon SRW-5000. In keeping with the design of the Canon R-1, the refraction measurement and participant fixation arrangement was via a large beamsplitter which reflects near infrared wavelengths and transmits visible wavelengths. The measurement of refractive error is achieved by image analysis of the size and shape of a ring of near infrared light (wavelength 850 nm[12]), rather than the moving lens carriage grating focus principle employed by the Canon R-1[2]. A motorised lens system first brings the image of the ring into focus if required (hence, continuous measurement could be facilitated without physical adaptation)[12], followed by the image analysis process. The image of the ring is smaller in hypermetropia, larger in myopia, and oval in astigmatism[12]. The wavelength of the infrared source in the SRW-5000 places it at the upper end of the visible spectrum. This has potential to influence dark focus (tonic accommodation) measurements; the Canon R-1 measurement system uses a higher wavelength source of 930 nm[13].

Summary of original paper

The original clinical evaluation paper of the performance of the SRW-5000 in adult participants was published in OPO in 2001[1] alongside a further validation of the instrument in children [14]a technical paper on computer interfacing for automatic output of refraction data [15]and a method for conversion of the instrument to allow continuous recording of accommodation[12]. These papers reported on the first generation instrument in a series of devices marketed under the Shin Nippon and Grand Seiko brands.

The validation of the instrument was carried out by comparison with the traditional 'gold standard' of non-cycloplegic subjective refraction. The refraction end point was the most positive or least negative sphere power to give best visual acuity, and cylindrical component determined by Jackson crossed-cylinder. Static retinoscopy was used as a starting point for the subjective refraction. Refraction data were decomposed into vector components using the method of Thibos and colleagues[16], producing mean sphere, J_{180} and J_{45} values. Treatment of refractive error data in this way enables straightforward mathematical analysis, decomposing the complexity of the standard clinical sphero-cylindrical form.

The method of Bland and Altman[17] was used to assess the performance of the SRW-5000 against standard subjective refraction. Comparisons of the sphere power, mean sphere, cylinder power and astigmatic vectors (J_{180} and J_{45}) were made for right and left eyes separately[18]. Figure 1 shows a reprint of Figure 2A from the original paper; a Bland-Altman plot of spherical power and spherical equivalent (sphere + 0.5cylinder). The data show statistically significant differences between the SRW-5000 and subjective refraction. For sphere power, the SRW-5000 gave on average a more positive refraction than the subjective method (+0.16 ± 0.44 D; $P < 0.001$); statistical power achieved was 0.95. Similarly, the mean sphere power was also more positive when measured by SRW-5000 (+0.15 ± 0.46 D; $P < 0.001$); adequate statistical power of 0.90 was achieved.

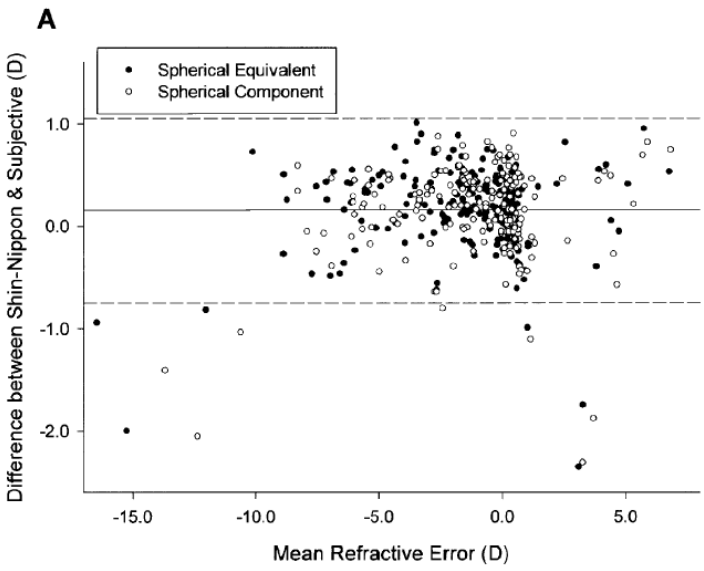

Figure 1. Difference versus mean plot for sphere power and spherical equivalent refraction measurements to show the validity of the SRW-5000 against subjective refraction.

Performance of the SRW-5000 in terms of measurement of astigmatism was also good. J_{180} and J_{45} vector components were on average within 0.10 DC of the subjective result. Although statistically significant, this difference was not clinically significant. When considered in isolation, the actual cylinder power was no different between the SRW-5000 and subjective refraction (average cylinder -0.74 ± 0.81 DC vs -0.75 ± 0.83 DC respectively; P = 0.76).

The SRW-5000 also demonstrated an impressive level of repeatability: when the autorefraction measurements were repeated on a subset of 50 eyes 1-2 weeks after the initial measurement. Table 1 shows data from Table 2 in the original paper.

Table 1. Reprint of Table 2 from the original clinical evaluation paper[1].

Table 2. Difference in refractive components of the SRW-5000 autorefractor found between different sessions

	MSE	J_0	J_{45}	Sphere	Cylinder
Mean difference	0.04	0.01	− 0.02	− 0.02	− 0.03
S.D. of differences	0.22	0.12	0.12	0.24	0.24
Within ±0.25 D (%)	74	–	–	67	65
Within ±0.50 D (%)	97	–	–	89	97
Within ±1.00 (%)	100	–	–	100	100

Update on the Shin-Nippon autorefractor

Application of the SRW-5000 to optometry and vision science experiments has been wide ranging. A search using Web of Science (accessed August 2015) for the topic "SRW-5000" reveals 70 papers with over 1100 total citations; a clear indication of the impact of this instrument on optometry and vision science research. Of particular note are the efforts made by researchers to adapt the instrument to increase functionality and measurement capability.

A further development of the research applications of the SRW-5000 was additional work on the continuous recording of pupil size, alongside the continuous recording of accommodation [19]. The instruments are also shipped under the commercial name Grand Seiko. The circular infrared light ring projection used in earlier instruments was replaced by a three arc segmented ring. A further development was the use of parallel horizontal and vertical lines in the form of an incomplete square.[19] The effect of these modification in the projected target, but not in the mechanism of action, of the instrument other than allowing measurement with a smaller pupil size has not been tested, but each model of the instrument family has shown similar validity and repeatability.[1,14,15,19,24,26,FR-5000]

As a research tool, the SRW-5000 has been of great value in the study of accommodation. Researchers at Aston University used the device to study the profile of autonomic innervation of ciliary smooth muscle with a view to determining inter-subject variability in access to sympathetic innervation, [20] and whether a sympathetic deficit is a factor in early adult-onset myopia [21]. Adaptations of the SRW-5000 continuous recording facility[12] were first used in this series of experiments. The high temporal frequency of the refraction measurements, usually in the range 20 to 60 Hz (dictated by the frame rate of the camera imaging the reflected measurement ring), provided capacity for the study of dynamic accommodation responses and microfluctuations in accommodation. Further work from this research laboratory used the SRW-5000 continuous recording system to study the correlation between accommodative demand and heart rate. Data showed an influence of sustained accommodation on heart rate; this being manifest as an increase in heart rate with increased closed-loop accommodative demand[22, 23].

The instrument has undergone a number of developments to improve clinical and research utility. The next production model in the range of devices was the NVision-K 5001, which has demonstrated a similar level of validity and repeatability to the SRW-5000[24]. This device included an autokeratometer function, and was built on a slightly smaller chassis compared to the SRW-5000. Further work on the NVision-K 5001 has shown validity of the internal methods used to arrive at a single sphere / cylinder x axis representation from the individual refraction measurements[25]. Unfortunately the external video output of the autorefractor camera was swapped for the autokeratometer system, excluding the facility of continuous recording of accommodation. Following this, the WAM-5500 device was developed. This instrument included the facility to measure dynamic accommodation responses with manufacturer-supplied software, but only at a temporal frequency of up to 5 Hz[26] . There was also a portable measurement head version of the device, although it seems few of these instruments were produced.

[Wolffsohn,JS Ukai,K Gilmartin,B (2006) Dynamic measurement of accommodation and pupil size using the portable Grand Seiko FR-5000 autorefractor. Optometry and Vision Science. 83, 306-310.]

Similar to the Canon R-1, the SRW-5000's open-view arrangement for stimulus presentation not only provides opportunity to vary accommodation stimulus (in both free space and using Badal lens systems), but also enables measurement of peripheral refraction, and allows the potential to combine the measurement of refraction or accommodation with other measurement platforms (e.g. ocular biometry). Alderson and colleagues used the different wavelengths of the SRW-5000 (850 nm) and the Zeiss IOLMaster (780 nm[27]) to combine the measurement systems into a single platform, thus enabling simultaneous monitoring of accommodation responses and single-shot readings of axial length[28].

Measurement of refractive error at points away from the visual axis are of great importance in myopia control research, and in more basic understanding of the link between eye shape and peripheral refraction[29]. Current work in myopia control has highlighted the potential impact of the position of the peripheral image shell in relation to the retina on myopia progression[30,31] . A number of methods have been shown to reduce the rate of myopia progression, including multifocal contact lenses[32] and orthokeratology[33]. A common theme in these methods is the placing of the peripheral image in front of (i.e. myopic with respect to) the retina. Peripheral refraction measurements at baseline and with a myopia control lens in place are therefore important and will perhaps in the future help to refine the actual amount of off-axis myopic defocus prescribed for a patient. These data will also help to resolve the debate over the exact mechanism by which dual focus and peripheral refraction manipulation techniques exert their myopia control effects[34]. Clearly, the validity and repeatability of instrumentation for the measurement of peripheral refraction is a key factor in the design of clinical trials for myopia control techniques. A study of instrument alignment during peripheral refraction measurements was undertaken using a second generation instrument (the NVisionK 5100). The study by Ehsaei and colleagues showed, in ten healthy eyes under cycloplegia, that peripheral refraction results could vary as a function of instrument alignment. Acceptable positions for alignment, at least in the horizontal meridian, would be obtained if the instrument was placed co-incident with a point halfway between the pupil centre and the corneal reflex[35]. Moore and Berntsen[36] assessed repeatability of central and peripheral autorefraction measurements with the WAM-5500 instrument in normal eyes and those treated by orthokeratology. In normal eyes, the between-visit repeatability (defined as 1.96 x SD of the mean difference between visits) of spherical equivalent autorefraction measurements was ±0.21 D centrally, rising to ±0.73 D at 40 degrees nasally and ±0.88 D at 40 degrees temporally. Astigmatic vectors showed 40 degree nasal repeatability of ±0.71 D and ±0.39 D for 40 degrees temporally for J_0, and ±0.30 D and ±0.36 D respectively, for these positions for the J_{45} vector. The repeatability of the instrument was considered sufficient for valid use in determining peripheral defocus in studies aiming to slow the progression of myopia[36].

When an individual views a distant target under closed-loop conditions immediately following completion of a sustained near-task an excessive accommodative response may be induced [i.e. a lead of accommodation termed nearwork-induced transient myopia (NITM)] [37]. It has been proposed that the relatively small amounts of retinal defocus produced (typically around 0.2 of a dioptre sustained for over 60 seconds) may ultimately stimulate axial elongation. The open-view design features of both the Canon R-1 and SRW-5000/WAM-5500 are particularly well suited to the investigation of NITM and investigations have been carried out on NITM in adults (SRW-5000[38,] , Canon R-1[39]) and children (SRW-5000)[40] and on anisometropia in adults (WAM-5500) [41] .The proposal that the susceptibility of early-and late-onset myopes to NITM may be attributable to impaired sympathetic innervation in myopia has also been reported for adults using the Canon R-1[42].

Conclusion

The SRW-5000 open view autorefractor and its derivatives have proved to be a significant addition to research laboratories in optometry and vision science. The original clinical evaluation paper[1] showed an impressive degree of validity and repeatability. Instruments developed subsequently also showed good performance and increased measurement capabilities. Research groups in a number of laboratories have undertaken development work to increase further the utility of the suite of instruments, thus opening up more research opportunities in peripheral refraction measurement, accommodation studies, and ocular biometry.

Acknowledgements

The original work was supported by a postgraduate Research Scholarship to EAH Mallen from the College of Optometrists. S Tsujimura was supported by the Leverhulme Trust. The authors have no proprietary interest in any of the instruments mentioned in this paper.

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Biographies

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James Wolffsohn is Professor of Optometry and Deputy Dean of Life and Health Sciences at Aston University UK. He completed his PhD at Cardiff University examining the accommodative response to virtual imagery using the Canon R-1 and after a clinical/research position at the University of Melbourne, converted the SRW-5000 to continuous recording in collaboration with Bernard Gilmartin after commencing a lectureship at Aston University.

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