1040-5488/15/9210-1003/0 VOL. 92, NO. 10, PP. 1003–1011
OPTOMETRY AND VISION SCIENCE

ORIGINAL ARTICLE

Comparing Autorefractors for Measurement of Accommodation

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ABSTRACT

Purpose. To compare the static and dynamic accommodative responses measured with the WAM-5500 and the PowerRef-II autorefractors.

Methods. The dynamic and static monocular accommodative responses were measured with the WAM-5500 and the PowerRef-II instruments in 30 pre-presbyopic patients (23.66 [±3.19] years). The spherical equivalent was measured at 0.00, 2.50, and 5.00 diopters (D) of accommodative stimulation for the static measurements. The subjective refraction was also determined. Dynamic accommodation was measured for abrupt changes of stimulus vergence of 2.00 D. Mean and peak velocities of accommodation and disaccommodation were evaluated. For the PowerRef-II, dynamic measurements were calculated for sampling frequencies of 5 and 25 Hz.

Results. For far distance static results, the differences between subjective and WAM-5500 measurements were 0.07 (±0.21) D ($p = 0.093$) and those between subjective and PowerRef-II measurements were 0.70 (±0.47) D ($p = 0.001$). The difference in the response measured with both instruments was 0.08 (±0.32) D ($p = 0.194$) for 2.50 D and −0.32 (±0.48) D ($p = 0.001$) for 5.00 D of stimulation. For the dynamic mode, the PowerRef-II at 25 Hz measured faster mean and peak velocities of accommodation and disaccommodation than the WAM-5500, with statistically significant ($p < 0.05$) differences of 0.68 (±1.01), 0.67 (±0.98), 1.26 (±1.19), and 1.42 (±1.53) D/s, respectively. With a sampling frequency of 5 Hz for the PowerRef-II, these differences, which were statistically significant ($p < 0.05$), were reduced to 0.52 (±0.90), 0.49 (±0.91), 0.83 (±1.07), and 0.83 (±1.31) D/s, respectively.

Conclusions. There is good agreement between subjective refraction and WAM-5500 measurements. In contrast, the PowerRef-II produced more hyperopic results. There were no differences among instruments at 2.50 D of static stimulation; however, differences were found at 5.00 D. In the dynamic measurements, the PowerRef-II measured faster velocities, partly attributed to the difference in the sampling frequency.

(Optom Vis Sci 2015;92:1003–1011)

Key Words: accommodation, accommodative response, static, dynamic, WAM-5500, PowerRef-II

Accommodation, defined as the dioptric change of the crystalline lens of the eye,[1] enables people to obtain clear images at different distances. Presbyopia, the progressive loss of amplitude of accommodation with age,[2] has been widely investigated because it eventually affects the whole population. Accommodation measurements can be indicative of different diseases affecting the accommodative system[3] and also binocular vision.[4] Additionally, in the past few years, there is an increasing interest in restoration of accommodation,[5] by means of intraocular lenses and surgical treatments. To quantify these techniques, precise measurements of the accommodation are necessary.

Accommodation can be static or dynamic. Static accommodation is measured under different stimulus conditions. The most common static measurement is the maximal/total amplitude of accommodation. Other static measurements are the accommodative–stimulus response curve and lag of accommodation. In each case, the measure is the degree of accommodation under specified conditions. Dynamic accommodation response is evaluated over a specified short period and is less commonly measured than static measurements. Dynamic measurements such as accommodative velocity, latency, and response time are currently laboratory based and still not typically applied to clinical work.

Static and dynamic accommodation can be measured both subjectively and objectively. Subjective techniques tend to overestimate

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the accommodative response.[6] To circumvent the dependence on the participant's response, objective measurements such as retinoscopy,[7] autorefraction,[8] aberrometry,[8] and double-pass systems[9] are being increasingly used.

Dynamic retinoscopy is the objective technique most commonly used in clinical practice.[7] However, it is difficult to perform and it can be considered partially subjective as it is dependent on the examiner. An automated alternative is photorefraction,[10,11] based on the same principle as dynamic retinoscopy but the examiner does not assess the neutral point. A commercial instrument based on this principle (PowerRefractor, Plusoptix) previously validated[12] is no longer commercially available. The PowerRef-II is the successor of the PowerRefractor, based on the same principle, and its usefulness for static and dynamic accommodation measurements has been demonstrated[13]; it now is the reference instrument in accommodation measurements documented in several research studies.[13–15]

Autorefraction is also widely used in research accommodation measurements and a number of autorefractors using different principles are available. Seidemann and Schaeffel[16] highlighted the great variability of results when measuring accommodation with different autorefractors, explained by the different principles upon which they are based and factors such as the accommodative stimulus. The Canon Autoref R-1,[17] an open-field autorefractometer that can simulate natural vision conditions, became widely used in research accommodation measurements and was used in several studies on accommodation.[18–21] Whereas the Canon Autoref R-1 is no longer available, new open-field autorefractometers such as the Grand Seiko WAM-5500[22] or Shin-Nippon NVision-K 5001 (also branded as the Grand Seiko WR-5100K)[23] are now commercially available. The Grand Seiko WAM-5500 has become a reference instrument in accommodation studies.[24–26]

The goal of this study was to compare the static and dynamic accommodative measurements obtained with the PowerRef-II and the Grand Seiko WAM-5500, two of the most widely used in research to assess accommodation. To our knowledge, no previous studies have compared these two instruments.

METHODS

Subjects

This prospective study was conducted on healthy young adults recruited from the staff and students of the Polytechnic University of Catalonia according to the tenets established by the Declaration of Helsinki. All subjects gave their written informed consent after receiving a written and verbal explanation of the nature of the study; the study was approved by the Hospital Mutua de Terrassa Ethics Committee.

The criteria for inclusion were best spectacle-corrected visual acuity of 0.00 logMAR (logarithm of the minimum angle of resolution) or better, and no history of any ocular condition, surgery, and/or ocular pharmacological treatment. Patients wearing spectacles were excluded to avoid interferences generated by the reflex of the lens; only emmetropic and contact lens wearers were included.

Thirty subjects (14 male and 16 female subjects) met the inclusion criteria. The mean (±SD) age was 23.66 (±3.19) years (range, 20 to 32 years). The mean (±SD) uncorrected visual acuity was 0.49 (±0.65) logMAR (range, 1.30 to −0.08), and the mean (±SD) best spectacle-corrected visual acuity was −0.02 (±0.03) logMAR (range, 0.00 to −0.08). The mean (±SD) spherical refractive error was −1.15 (±1.65) diopters (D) (range, −6.00 to +1.00 D), and the mean (±SD) cylindrical refraction was −0.40 (±0.38) D (range, 0.00 to −1.00 D).

Instrumentation and Setup

PowerRef-II

The PowerRef-II is based on infrared retinoscopy. It automatically determines sphere, cylinder, and spherical equivalents of the refractive state of the eye. The spherical refraction ranges from +5.00 to −7.00 D and the pupil diameter ranges from 3 to 8 mm, with the best results obtained in pupils larger than 4 mm.[13] The PowerRef-II obtains dynamic refractive state measurements at a sampling frequency of 25 Hz. It allows open-field fixation, which can simulate natural vision conditions for accommodative measurements; it can also perform simultaneous binocular measurements.

WAM-5500

The Grand Seiko WAM-5500 is an open-field autorefractor that projects a ringlight and measures its deformation after reflection from the retina through the optics of the eye to calculate the refractive state of the eye for the sphere, cylinder, and spherical equivalents. The measurable range of spherical refraction is ±22.00 D, the minimum pupil diameter is 2.3 mm,[22] and the vertex distance can be adjusted. It can measure the refractive state in static and dynamic modes at a frequency of 5 Hz connecting the autorefractor to a computer. The WAM-5500 allows binocular accommodative stimulation, but the measurements are monocular.

Setup

The setup for the PowerRef-II and WAM-5500 is shown in Fig. 1A, B, respectively. A fixation target was shown at adjustable distance in both instruments. To simulate the open-field viewing conditions of the WAM-5500 with the PowerRef-II (Fig. 1A), a hot mirror was used, as previously used by Jainta et al.[13] The patient used a chinrest and the distance from the PowerRef-II to the patient's pupil plane was 1 m. In the PowerRef-II configuration, the hot mirror was at 50 mm from the pupil plane and the field of view was 28 degrees. The WAM-5500 instrument was at 50 mm from the patient's pupil plane and the (vertical) field of view was 32 degrees.

Measurement Procedure

All measurements were performed by the same experienced examiner. Measurements were carried out in only one eye: because of the configuration setup, the left eye was chosen in all cases. The right eye was occluded. Subjects wore contact lenses with their best refractive correction or no correction in emmetropes.

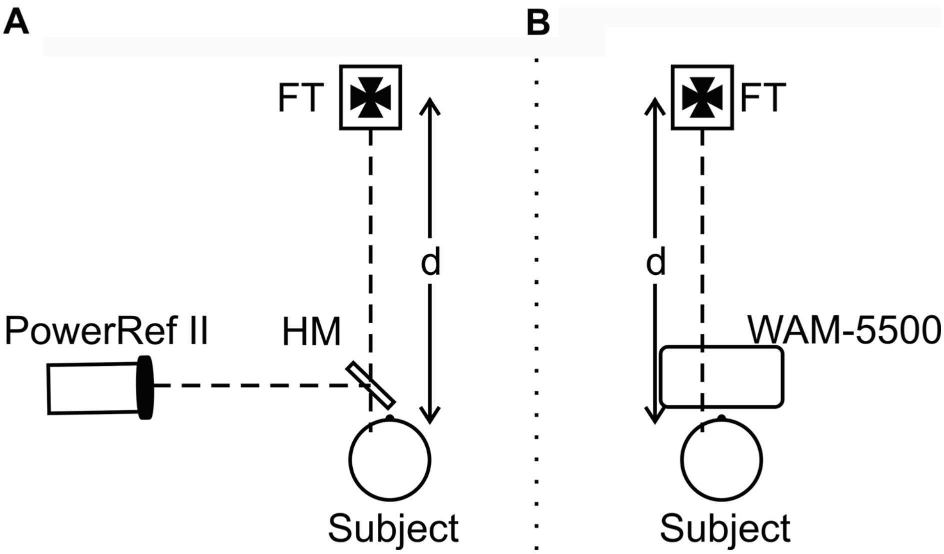

FIGURE 1.

Setup for the static and dynamic accommodative response measurements. (A) The setup for the PowerRef-II with a fixation target (FT) at adjustable distance (*d*) seen through a hot mirror (HM). (B) The setup for the WAM-5500 with a fixation target (FT) at adjustable distance (*d*).

First, an optometric examination was performed and refractive state was measured by means of streak retinoscopy and subjective refraction, with the endpoint criteria of minimum negative lens power to maximize visual acuity. Uncorrected visual acuity and best spectacle-corrected visual acuity were noted. The amplitude of accommodation was measured by the Sheard or negative lens method and accommodative facility was measured by ±2.00 D flippers.

After optometric examination, accommodation was measured with both instruments. For each instrument, static accommodation followed by dynamic accommodation were measured. The sequence of the instruments was randomly chosen for each patient to avoid a learning effect. For all measurements, the vertex distance of the WAM-5500 was set at 0 mm, because the subjects wore contact lenses or no correction. Measurements with both instruments were performed on-axis, controlling the centration with the cameras from the instruments. The illumination of the room was the same for all participants (350 lux) and the pupil diameter obtained with this illumination for far vision was 5.29 (±0.68) mm.

Static Measurements

The mean spherical equivalent of five consecutive measurements was obtained for three accommodative stimuli: 0.00, 2.50, and 5.00 D. Measurements started from the far stimulation (0.00 D) and ended at near (5.00 D). Accommodative response was determined as the absolute value of the spherical equivalent difference between the near distance (2.50 or 5.00 D) and the far distance (0.00 D).

Dynamic Measurements

For dynamic accommodative response measurements, the accommodative stimulus changed from 1.00 to 3.00 D in 2.00-D steps. Two fixation targets were used to obtain abrupt changes with the accommodative stimulus: one at 1.00 m (1.00 D of stimulus) and the second at 0.33 m (3.00 D of stimulus). The test at 0.33 m was connected to a motor and appeared and disappeared in 64 milliseconds. The period of the cycle was 10 seconds, and six cycles were repeated for each patient with a total duration of 60 seconds, as shown in Fig. 2. The spherical equivalent was measured and exported to a computer, where it was divided in six parts (each one corresponding to a cycle) and the mean step response was calculated. From the mean response, the mean accommodation and disaccommodation velocity and the velocity peaks of accommodation and disaccommodation were calculated as previously described.[27] The amplitude of the response is calculated as the maximum difference in the step response. The mean accommodation and disaccommodation velocities are calculated as the absolute value of the dioptric change divided by the time over the interval 10 to 90% of the total step, 80% of the absolute value. The peaks of accommodation and disaccommodation velocities are calculated as the absolute value of the maximum dioptric change per time unit. Because of sampling frequency differences between instruments, dynamic calculations obtained with the PowerRef-II were recalculated to reduce its sampling frequency from 25 to 5 Hz. The data obtained from the measurements were thus filtered, taking into account just one value of every five.

Statistical Analysis

The static accommodative response measured with both instruments was compared with different methods, according to McAlinden et al.[28] First, the mean difference among instruments was calculated. A Bland and Altman analysis[29] was subsequently performed to study the agreement between instruments. This method plots the mean difference against the mean value and the corresponding limits of agreement, defined as 1.96 times the SD of the mean difference, within which 95% of the differences between measurements are expected to lie. To evaluate if there was any tendency in the differences to vary in any systematic manner over the range of measurements, the Pearson correlation coefficient and

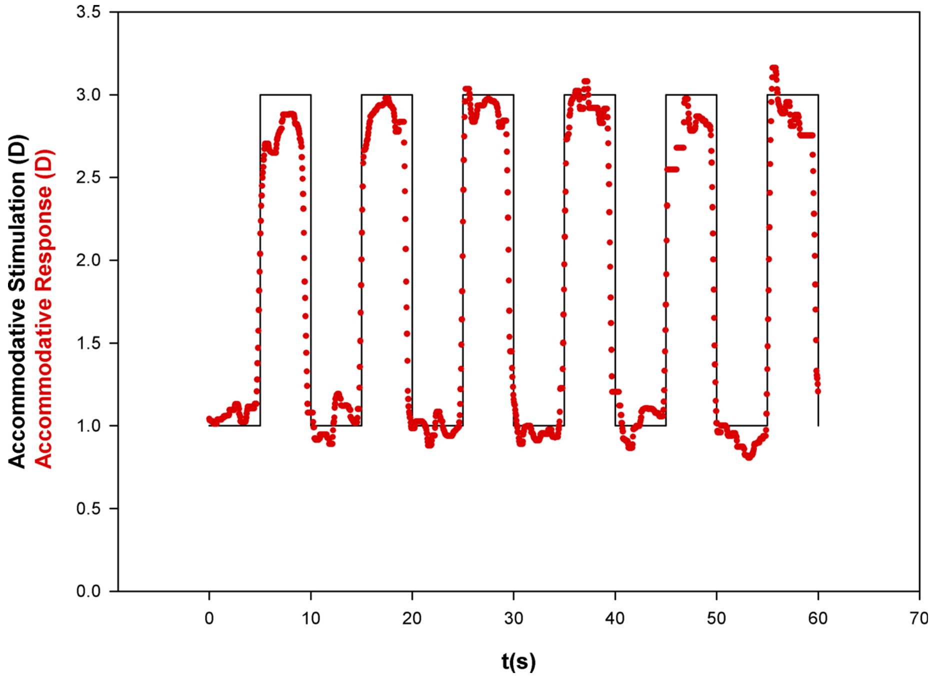

FIGURE 2.

Example of dynamic accommodative stimulation (black solid line) and response (black dots [red online]) through time (*t*) (D, diopters; s, seconds). A color version of this figure is available online at www.optvissci.com.

its significance were also used in the Bland and Altman plot. Finally, the Kolmogorov-Smirnov test was used to evaluate the normal distribution of all variables and a paired sample test was carried out to analyze if there were significant differences between the accommodative response measurements obtained with the two instruments.

For dynamic accommodative response measurements, the comparison procedure was similar to the static measurements: mean difference, limits of agreement, Bland and Altman plot, and paired sample test after evaluating the normality by means of the Kolmogorov-Smirnov test. Because of the large number of variables analyzed (mean and peak velocities of accommodation and disaccommodation), in each Bland and Altman graph, mean and peak absolute velocities were represented together.

Statistical analysis was performed using commercial SPSS software for Windows (version 17.0, SPSS, Chicago, IL). A p value of 0.05 was considered significant.

RESULTS

Static Accommodation

The results for far refraction of the spherical equivalent, where subjective refraction was compared with both objective techniques (WAM-5500 and PowerRef-II), are summarized in Table 1. The mean difference is calculated as the objective refraction obtained with the WAM-5500 or the PowerRef-II minus the subjective refraction. Thus, in objective measurements, positive values correspond to more hyperopic results. The WAM-5500 produced small differences with the subjective refraction, which were not statistically significant. The PowerRef-II objective refraction was 0.70 D more positive than subjective refraction, the limits of agreement were double that of the WAM-5500, and statistically significant differences were found. In both cases, the Kolmogorov-Smirnov test proved the normal distribution of the variables.

The static accommodative responses obtained with the WAM-5500 and the PowerRef-II were compared by pairs for the accommodative stimuli of 2.50 and 5.00 D. Results are shown in Table 2. The mean difference is calculated as the response of the WAM-5500 minus the PowerRef-II. Thus, positive values correspond to higher accommodative responses with the WAM-5500. The mean difference between instruments was close to zero at 2.50 D of stimulation; in contrast, higher accommodative response values were obtained with the PowerRef-II for the 5.00-D stimulation. The Bland and Altman plot is shown in Fig. 3 for accommodative stimulations of 2.50 and 5.00 D, with Pearson

TABLE 1.

Comparison of refraction (Rx) when measured subjectively (Subj) and objectively using the WAM-5500 (WAM) and the PowerRef-II (PR)

	Mean (±SD) difference, D	95% limit of agreement, D	Paired sample *t* test (p)
$Rx_{WAM} - Rx_{Subj}$	0.07 (±0.21)	(0.48, −0.34)	0.093*
$Rx_{PR} - Rx_{Subj}$	0.70 (±0.47)	(1.62, −0.22)	<0.001

The mean (±SD) difference, 95% limits of agreement, and the paired sample *t* test results are shown.
*No significant differences.

TABLE 2.

Comparison of accommodative response (AR) measurements using the WAM-5500 (WAM) and the PowerRef-II (PR)

	AS, D	Mean (±SD) difference, D	95% limit of agreement, D	Paired sample *t* test (p)
$AR_{WAM} - AR_{PR}$	2.50	0.08 (±0.32)	(0.71, −0.55)	0.194*
	5.00	−0.32 (±0.48)	(0.62, −1.26)	0.001

For the two accommodative stimulations (AS), the mean (±SD) difference between instruments, 95% limits of agreement, and the paired sample *t* test results are shown.

*No significant differences.

correlation coefficients of −0.499 (p = 0.005) and −0.712 (p < 0.001), respectively. Finally, after confirming the normal distribution of the values, the *t* test showed no differences at 2.50 D of stimulation but significant differences for 5.00 D.

Dynamic Accommodation

With regard to the mean velocity of accommodation and disaccommodation, the results for the WAM-5500 were 1.60 (±0.41) and 1.47 (±0.44) D/s; for the PowerRef-II at 25 Hz, 2.29(±1.03) and 2.14 (±0.96) D/s; and for the PowerRef-II at 5 Hz, 2.13 (±0.92) and 1.96 (±0.87) D/s. In Table 3, the comparison among the WAM-5500, the PowerRef-II at 25 Hz, and the PowerRef-II at 5 Hz is shown as the mean difference, limits of agreement, and *t* test performed after confirming the normal distribution of the variables. In the mean difference, positive results correspond to faster velocities with the first instrument compared; that is, when comparing the PowerRef-II at 25 Hz versus the PowerRef-II at 5 Hz, the mean difference is 0.16 D/s; thus, the PowerRef-II measures faster velocities at 25 Hz than at 5 Hz. The mean velocity measured with the WAM-5500 was slower than the mean velocity measured with the PowerRef-II for both 5 and 25 Hz. When comparing the mean velocity at 5 and 25 Hz, faster velocities were obtained with the higher frequency. There were statistically significant differences in all the comparisons.

The mean (±SD) peak of accommodation and disaccommodation velocities for the WAM-5500 were 2.35 (±0.54) and 2.32 (±0.62) D/s; for the PowerRef-II at 25 Hz, 3.61 (±1.21) and 3.74 (±1.45) D/s; and for the PowerRef-II at 5 Hz, 3.18 (±1.06) and 3.15 (±1.18) D/s. In Table 3, the comparison among the WAM-5500, the PowerRef-II at 25 Hz, and the PowerRef-II at 5 Hz is shown as the mean difference, limits of agreement, and *t* test performed after confirming the normal distribution of the variables. The peak velocity measured with the WAM-5500 was slower than that measured with the PowerRef-II for both 5 and 25 Hz. When comparing the peak velocity at 5 and 25 Hz, faster velocities were measured with the higher frequency. There were statistically significant differences in all comparisons.

A Bland and Altman graph (Fig. 4) summarizes the results for dynamic accommodative response. Fig. 4A shows the mean (crosshair) and peak (diamond) absolute value of the accommodation and disaccommodation velocities when comparing the WAM-5500 with the PowerRef-II at 25 Hz, where negative values in the difference (ordinate) correspond to higher velocities

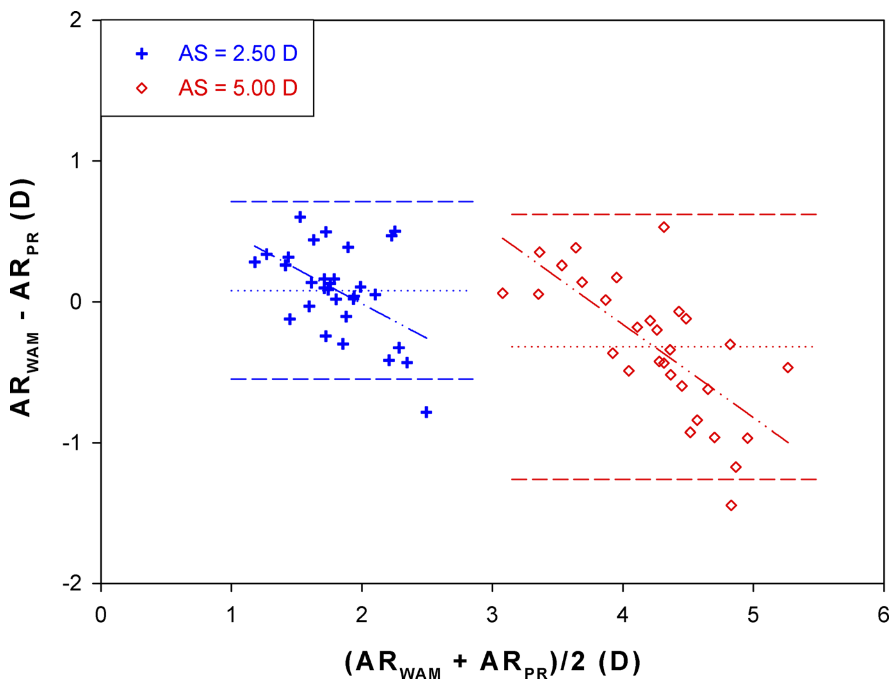

FIGURE 3.

Bland and Altman plots comparing the accommodative response (AR) measured with the WAM-5500 (WAM) and the PowerRef-II (PR) for accommodative stimulations (AS) of 2.50 (crosshair) and 5.00 D (diamond). Dashed lines indicate the 95% limits of agreement and dotted lines denote the mean value. Dash-dotted lines indicate the regression line. A color version of this figure is available online at www.optvissci.com.

TABLE 3.

Comparison in terms of mean (±SD) difference, 95% limits of agreement (LoA), and the paired sample *t* test of mean accommodative (V^A_{mean}) and disaccommodative (V^D_{mean}) velocity and peak accommodative (V^A_{peak}) and disaccommodative velocity (V^D_{peak}) measurements using the WAM-5500 (WAM) and the PowerRef-II at 25 Hz (PR 25 Hz) or 5 Hz (PR 5 Hz) sampling frequency

		WAM − PR 25 Hz	WAM − PR 5 Hz	PR 25 Hz − PR 5 Hz
V^A_{mean}, D/s	Mean (±SD) difference	−0.68 (1.01)	−0.52 (0.90)	0.16 (0.15)
	95% LoA	(1.30, −1.65)	(1.24, −1.38)	(0.45, 0.02)
	t test	0.003	0.009	0.000
V^D_{mean}, D/s	Mean (±SD) difference	−0.67 (0.98)	−0.49 (0.91)	0.17 (0.17)
	95% LoA	(1.25, −1.65)	(1.29, −1.36)	(0.50, 0.01)
	t test	0.003	0.014	0.000
V^A_{peak}, D/s	Mean (±SD) difference	−1.26 (1.19)	−0.83 (1.07)	0.43 (0.30)
	95% LoA	(1.07, −2.40)	(1.27, −1.86)	(1.02, 0.14)
	t test	0.000	0.001	0.000
V^D_{peak}, D/s	Mean (±SD) difference	−1.42 (1.53)	−0.83 (1.31)	0.59 (0.46)
	95% LoA	(1.58, −2.89)	(1.74, 2.09)	(1.49, 0.15)
	t test	0.000	0.005	0.000

measured with the PowerRef-II. The Pearson correlation coefficient for this case was −0.676 ($p < 0.001$). Fig. 4B plots the mean (crosshair) and peak (diamond) absolute velocities comparison for the PowerRef-II at 25 and 5 Hz, where positive values in the difference (ordinate) correspond to higher velocities measured with the PowerRef-II at 25 Hz. The Pearson correlation coefficient for this case was −0.694 ($p < 0.001$).

DISCUSSION

The WAM-5500 and the PowerRef-II are two of the most widely used instruments to investigate the accommodative response of the eye. This study compared the results of static and dynamic accommodation measurements when using these two instruments.

First, the results of refraction obtained by means of the two objective instruments (WAM-5500 and PowerRef-II) were compared with subjective refraction. The results showed a good agreement between the subjective and the WAM-5500 refraction, with a mean difference close to zero (0.07 D), relatively narrow limits of agreement (0.48, −0.34), and no statistically significant differences. In contrast, with the PowerRef-II, the mean difference with subjective measurements was high (0.70 D), the limits of agreement were wider (1.62, −0.22), and statistically significant differences were found. In a previous study[22] evaluating the WAM-5500, a good agreement between subjective and autorefractometer

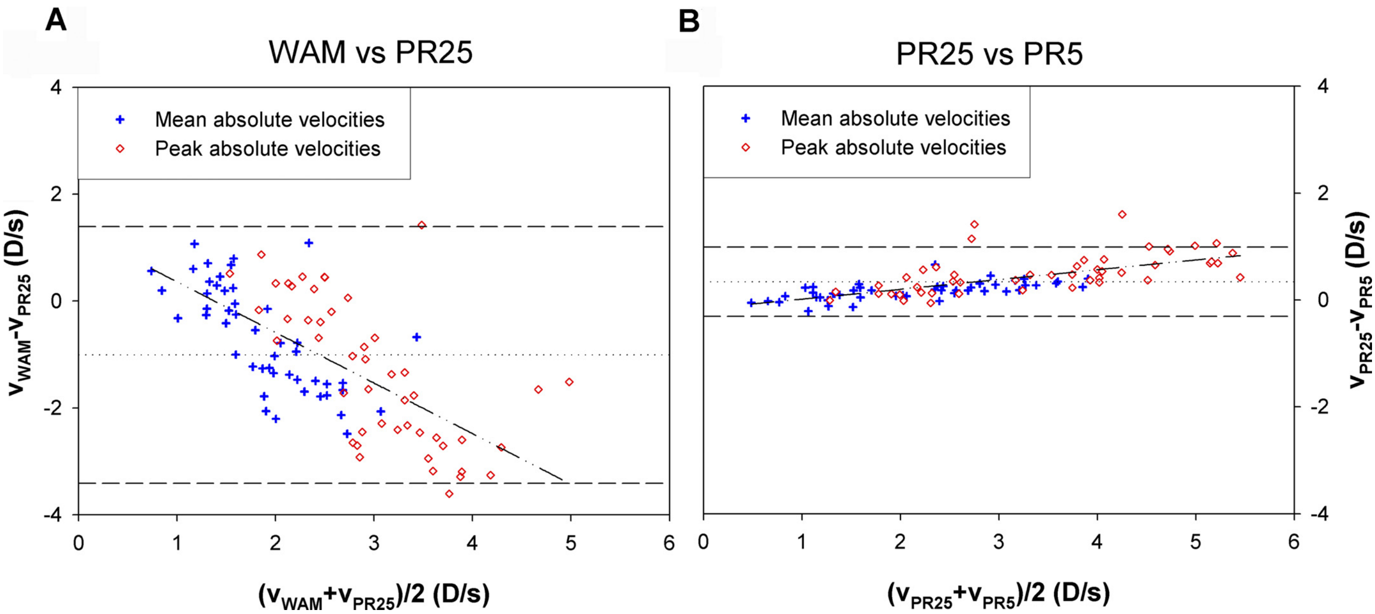

FIGURE 4.

Bland and Altman plots comparing the mean (crosshair) and peak (diamond) absolute value of the accommodation and disaccommodation velocities (*v*). (A) WAM-5500 (WAM) versus PowerRef-II at 25 Hz (PR25). (B) PowerRef-II at 25 Hz (PR25) versus PowerRef-II at 5 Hz (PR5). Dashed lines indicate the 95% limits of agreement and dotted lines denote the mean value. Dash-dotted lines indicate the regression line. A color version of this figure is available online at www.optvissci.com.

refraction was obtained, with a mean (±SD) difference of 0.04 (±0.41) D and no statistically significant differences (p = 0.21). On the other hand, the PowerRef-II tends to produce more hyperopic results, as shown in this study. Specifically, when comparing the PowerRef-II and subjective refraction, Jainta et al.[13] found statistically significant differences of +0.63 D; Choi et al.,[12] +0.59 D for the sphere; Gekeler et al.,[30] +0.41 D for the sphere; and Hunt et al.,[31] +0.05 D. When compared with other objective measurements, the PowerRef-II also showed more hyperopic results: Abrahamsson et al.[32] found a difference of +0.42 D using an autorefractometer and streak retinoscopy; Jainta et al.,[13] +0.59 D using an autorefractometer; Seidemann and Schaeffel,[16] +1.08 D using streak retinoscopy; and Gekeler et al.,[30] +0.43 D for the sphere using an autorefractometer. The only exception to this trend of more hyperopic results in PowerRef-II refraction is the results of Hunt et al.[31] comparing the PowerRefractor with an autorefractometer, with a difference of −0.20 D for the sphere. The subjective refraction data in the study of Hunt et al. showed a high SD, and the first version of the instrument was used (the PowerRefractor, as opposed to the PowerRef-II), which could explain the differences. Regarding the limits of agreement, the WAM-5500 also shows better concordance with the subjective refraction than the PowerRef-II. Although the limits of agreement with subjective refraction were between +0.50 and −0.50 in the WAM-5500, these limits increased by more than double with the Power-Ref-II. Overall, our results agree with previous studies that obtained a refraction with the WAM-5500 closer to the subjective and a more hyperopic PowerRef-II refraction.

When studying the static accommodative response measured by means of the WAM-5500 and the PowerRef-II at 2.50 D of stimulation, small (0.08 D), nonsignificant differences between instruments were found. On the other hand, when increasing the accommodative stimulation to 5.00 D, the differences increased to 0.32 D (highest accommodative response measured with the PowerRef-II) and became statistically significant. The Bland and Altman plot clearly shows the enlargement of the differences between the WAM-5500 and PowerRef-II instruments as the accommodation increases. In a previous article on the effect of phenylephrine on accommodation,[33] a similar effect was found to a 4-D stimulus. Similarly, Jainta et al.[13] found that the slope of the accommodative response as a function of the stimulation was significantly higher for the PowerRef-II (slope of 0.99) compared with the Canon R-1 (slope of 0.88); that is, the PowerRef-II measures higher accommodative responses. To verify this finding, a small study was carried out in two eyes with the accommodation paralyzed with tropicamide.[34] The accommodative response was measured with both instruments with eyes wearing contact lenses of powers from 0.00 to 5.00 D in 1.00-D steps, a procedure similar to that used by other authors for calibration purposes.[24] Contact lenses, and not trial lenses, were used to avoid reflexes in the instruments. Contact lenses were fitted with the centration controlled, and time to adaptation before measurements was allowed. Fig. 5 shows the results for the PowerRef-II and WAM-5500, where the PowerRef-II measures higher accommodative responses. The slope difference among instruments (0.05) is consistent with the data obtained in the whole population for 2.50- and 5.00-D stimulations, because the slope difference would predict an accommodative response difference of 0.12 D at 2.50 D of stimulation (difference measured in patients, 0.08 D) and 0.25 D at 5.00 D of stimulation (difference measured in patients, 0.32 D). The WAM-5500 autorefractor is essentially the same as the WR-5100K and

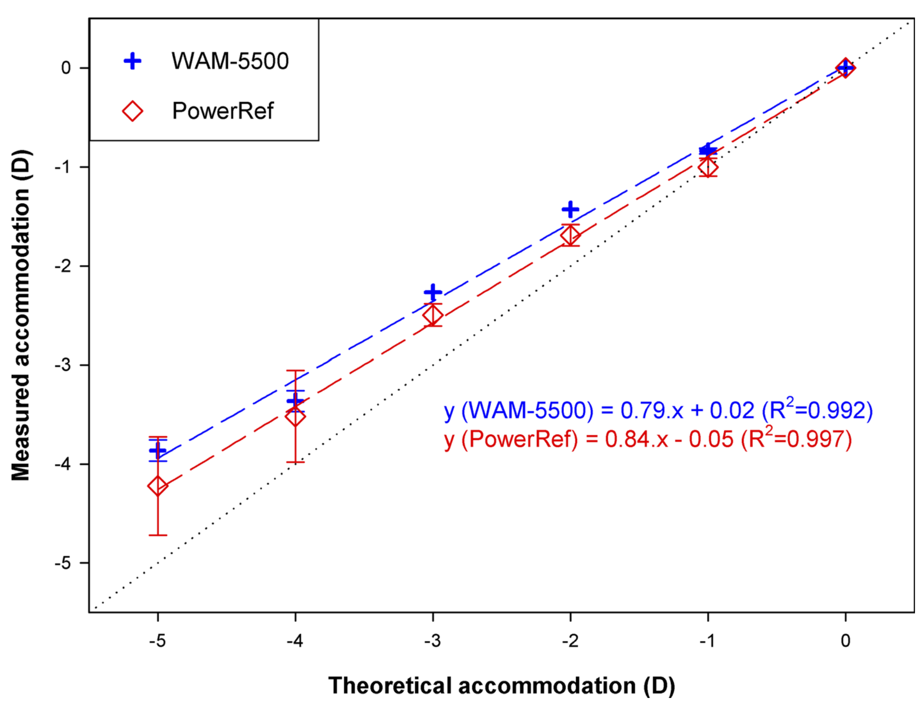

FIGURE 5.

Accommodative response measured with the PowerRef-II and WAM-5500 in accommodation cyclopleged eyes wearing contact lenses of known power (theoretical power) (D, diopters). Dashed lines indicate the regression line and the dotted line indicates the line of equality. A color version of this figure is available online at www.optvissci.com.

Nvision-K5100 autorefractors for the static mode.[23,24] Thus, the conclusions for the static measurements (refraction and accommodation) can be extended to these two autorefractors (WR-5100K and Nvision-K5100).

With regard to the dynamic accommodation and disaccommodation mean and peak velocities, our results were in the same range as those obtained by Heron et al.[27] but slower than those obtained by other authors.[35–37] This could be attributed to the method used to calculate the velocity. As previously mentioned, we used the method proposed by Heron et al., whereas different methods were used by the other authors.

When comparing the WAM-5500 and the PowerRef-II at a sampling frequency of 25 Hz, the results obtained with the PowerRef-II were faster and the differences were statistically significant (Table 3); a negative difference corresponds to faster velocities measured with the PowerRef-II, because the difference is calculated as the results of the WAM-5500 minus the results from PowerRef-II. If the differences shown in Table 3 are expressed in percentage (considering the WAM-5500 value as reference), there will be a difference of 44% (43% for accommodation and 45% for disaccommodation) in mean velocity and 57% (53% for accommodation and 61% for disaccommodation) in peak velocity. In the Bland and Altman plot (Fig. 4A), one can clearly see the increasing difference between the WAM-5500 and the PowerRef-II as faster velocities are measured, with a statistically significant correlation of −0.676. The differences in our study were significant, probably because of the differences between the measurement principles of the instruments and the sampling frequency (five times slower in the WAM-5500 than in the PowerRef-II).

To study if the instruments caused the differences, the sampling frequency of the PowerRef-II was reduced from 25 to 5 Hz, which is the sampling frequency of the WAM-5500. The comparison with the WAM-5500 and the PowerRef-II at 5 Hz is shown in Table 3. The differences were smaller than those for the previous comparison but statistically significant. PowerRef-II at 5 Hz measured faster velocities than the WAM-5500; the differences for the mean velocity were 33.5% (33% for accommodation and 34% for disaccommodation) and those for the peak velocity were 35.5% (35% for accommodation and 36% for disaccommodation). To study the impact of sampling frequency, the results obtained with the PowerRef-II at 25 and 5 Hz were compared and statistically significant (Table 3), although smaller than previously reported. Expressed in percentages, the differences were 10.5% (10% for accommodation and 11% for disaccommodation) for the mean velocity and 22% (18% for accommodation and 24% for disaccommodation) for the peak velocity. The Bland and Altman plot in Fig. 4B shows greater differences as velocity increases (statistically significant correlation coefficient = −0.694). Compared to Fig. 4A, the regression line slope is less, illustrating the lower impact of sampling frequency compared with instrument difference.

From the dynamic results, there are substantial differences between these instruments. The difference between the WAM-5500 and the PowerRef-II under normal conditions (25 Hz) was 44% for the mean velocity and 57% for the peak velocity. The differences attributed to the instruments (WAM-5500 vs. PowerRef-II at 5 Hz) induce an error of 33.5 and 35.5% for the mean and peak velocities, respectively. The error attributable to the sampling frequency (PowerRef-II 25 Hz vs. PowerRef-II 5 Hz) is 10.5 and 22% for the mean and peak velocities.

We concluded that for far vision refraction, the WAM-5500 is closer to the subjective refraction than the PowerRef-II is. In static accommodation, there are differences among instruments but only significant at higher stimulations (5.00 D). For dynamic accommodation, the differences between the WAM-5500 and the PowerRef-II are mainly attributed to the instrument but also to the sampling frequency for the measurement.

ACKNOWLEDGMENTS

This study was partially funded by the Spanish Ministry of Science and Innovation with the project grant DPI2011-30090-C02-01 and the European Union. This work has been partially presented at the Vision Science and Eye Research Meeting 2014, Santiago de Compostela, Spain.

Received December 1, 2014; accepted April 23, 2015

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