· Investigation ·

Auto-refraction versus subjective refraction in different phakic and pseudophakic conditions: the Tehran Geriatric Eye Study (TGES)

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Abstract

● **AIM:** To compare the subjective refraction data with non-cycloplegic auto-refraction findings in the geriatric population above 60 years of age according to the different crystalline lens conditions.

● **METHODS:** This report is a part of the Tehran Geriatric Eye Study (TGES) that was conducted from January 2019 to January 2020 on elderly population 60 years of age and above in Tehran. The samples were selected by multi-stage stratified random cluster sampling. Of 3791 individual invitees, 3310 (response rate: 87.3%) participated in this study. All study participants underwent non-cycloplegic auto-refraction (auto-refractometer/keratometer Nidek ARK-510) and subjective refraction.

● **RESULTS:** Regarding the sphere, eyes with mixed cataract had the worst limits of agreement (LoA: -1.24 to 0.87) and the best agreement was related to the pseudophakic eyes (LoA: -0.83 to 0.54). The highest (0.27±0.31 D) and lowest (0.21±0.27 D) differences between the two methods regarding the cylinder power were observed in eyes with cortical cataract and normal eyes, respectively. The worst LoA between the two methods in measuring the cylinder power was related to the eyes with mixed cataract (LoA: -0.44 to 0.96). Regarding the J_0 (horizontal/vertical components of astigmatism), the mean values of J_0 obtained by auto-refraction were tended more toward against the rule direction in all crystalline lens conditions, and the two methods had the greatest difference in cortical cataract cases (0.05±0.17 D). Regarding the J_{45} (oblique components of astigmatism), the lowest (0±0.11 D) and highest (-0.01±0.12 D) differences were observed in normal eyes and eyes with cortical cataract, respectively.

● **CONCLUSION:** The auto-refractometer/keratometer Nidek ARK-510 results in the elderly with different phakic and pseudophakic conditions do not correspond well with subjective refraction findings. This discrepancy in spherical findings is more pronounced in individuals with mixed cataract than in other cases.

● **KEYWORDS:** refraction; subjective; geriatric; non-cycloplegic; autorefraction

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INTRODUCTION

Subjective refraction is based on feedback received from the patient and is known as the gold standard of refraction[1-3]. However, auto-refraction has become more popular in clinical practice and epidemiological studies due to its high measurement speed, saving on examination time, and patient's acceptance[2,4-7]. Some studies have indicated that auto-refraction is reliable only in cycloplegic conditions, especially in the pediatric population[1,4,7-11].

The cycloplegia process significantly increases the examination time, causes the patient's discomfort and blurred vision and ultimately reduces the patient's satisfaction[12-13]. In addition, use in some special conditions is not indicated[14]. For this reason, many clinicians today correctly or incorrectly measure refractive errors and prescribe optical correction based on the net results of non-cycloplegic auto-refraction. On the other hand, the non-cycloplegic auto-refraction findings are commonly used in the field of epidemiological research[15-16]. However, some clinical studies suggested that patients may be dissatisfied with the spectacles prescribed based on pure auto-refraction results[17].

What most previous studies have indicated regarding the reliability of non-cycloplegic auto-refraction is that in this method compared to the subjective refraction and cycloplegic retinoscopy (the two accepted gold standard methods of refraction), an over-minus error may occur in the spherical component of refraction. This over-minus error is caused by the patient's accommodative effort[2,16]. The over-minus error in non-cycloplegic auto-refraction which has been reported in many studies, is more common in children and adolescents who have more active ocular accommodation[2].

According to the results of various studies, there is no concern about the occurrence of over-minus error over the age of 60y due to the lack of effective ocular accommodation[18-19]. However, the aging process causes ocular changes such as pupillary miosis and media opacity[20] that may cause errors in auto-refraction[21]. On the other hand, implantation of intraocular lenses during cataract surgery causes a pseudophakic condition in a large percentage of the elderly above the age of 60y, which may cause an auto-refraction error due to a change in ocular media[22]. The importance of refraction accuracy in the elderly cannot be overemphasized due to the high prevalence of cataracts[23] and cataract surgery where there is a need for high refraction accuracy in calculating the power of intraocular lenses with even small errors can cause refractive surprise after surgery[22]. Due to the importance of refraction in the elderly and the possible role of some contributing factors such as different types of lens opacity, the present report aimed to determine the agreement between the two methods of auto-refraction and subjective refraction according to the crystalline lens status in a geriatric population.

SUBJECTS AND METHODS

Ethical Approval Informed consent was obtained from all participants. The principles of the Helsinki Declaration were followed in all stages of this study. The protocol of the study was approved by the Ethics Committee of the National Institute for Medical Research Development (NIMAD) under the auspices of the Iranian Ministry of Health (ethics code: IR.NIMAD.REC.1397.292).

This report is a part of the Tehran Geriatric Eye Study (TGES) that was conducted from January 2019 to January 2020 in Tehran, the capital of Iran. The target population of TGES was all residents 60 years of age and older in Tehran. The samples were selected using the multi-stage stratified random cluster sampling method. The 22 municipality districts of Tehran were considered as strata, and a total of 160 clusters were selected proportionally to size from the 22 districts. Twenty people were systematically selected randomly from each cluster. After selecting the samples and explaining the objectives and steps of the study and ensuring the confidentiality of the information, all of them were invited to participate in the study. The study participants were then transported to the examination site free of charge within a pre-determined day. In the first step, informed consent was obtained from all study participants. Then, all subjects were interviewed to obtain complete demographic information. The complete ocular examinations were performed in the next stage.

First, all individuals underwent optometric examinations including visual acuity measurement, auto-refraction, and subjective refraction. The auto-refraction was performed by Nidek ARK-510 auto-refractometer/keratometer (Nidek Co. LTD, Aichi, Japan). The results were then checked by retinoscopy (Beta 200 retinoscope, HEINE Optotechnic, Herrsching, Germany).

Then uncorrected distance visual acuity (UCVA) was measured using an LED visual chart (Smart LC 13, Medizs Inc, South Korea) at a distance of 6 m. If the person had present glasses, a lensometry was performed. In the next step, subjective refraction was performed and the best-corrected distance visual acuity (BCVA) was recorded. The objective refraction findings were used as a starting point for subjective refraction.

The steps of subjective refraction included sphere power check, cylinder axis and cylinder power determination using Jackson cross-cylinder (JCC), and binocular balancing, respectively.

The red-green (duochrome) test was used as a monocular endpoint test to increase the precision of subjective refraction. To achieve the optimal retinal image position as well as the closest results to the patient's BCVA, the participant was asked to compare the sharpness of the chart's characters on the green versus red backgrounds. If the participant reported that the characters on the red background were sharper, blacker or more distinct, a -0.25 diopter (D) spherical lens was added. If the participant preferred the green background, a +0.25 D lens was added. The endpoint criteria used was the lens power at which the red and green sides were equally distinct. For subjects who did not arrive at equality of the two sides, the BCVA was recorded by considering the patient's preference in subjective refraction. The duochrome test was also used as a binocular balancing test. For this purpose, we placed the participant's eyes in a similar endpoint of the red-green test (equality endpoint for the two eyes or the similar preference of one background when equality could not be achieved). In subjects who were unable to report an equal red and green result, we considered optimal visual acuity based on their preference in subjective refraction for both eyes. Finally, anterior and posterior segment examination were performed using a slit-lamp biomicroscope (Slit lamp B900, Haag-Streit AG, Bern, Switzerland) by an ophthalmologist. The posterior segment examination was undertaken using a +90 D lens. Subjects with a history of any ocular surgery except cataract surgery were excluded from the study.

Definitions In this study, cataract cases were determined based on the World Health Organization (WHO) grading system[24]. Nuclear types of cataracts were diagnosed based on discoloration of the crystalline lens nucleus in optic section illumination, and opacities of grade 2 and above were defined as nuclear sclerosis cataract. Cortical and posterior sub-capsular (PSC) cataracts were also diagnosed and graded based on the shape and morphology of the crystalline lens opacity. Mixed cases were those with at least 2-grade opacity from each type of cataract.

Statistical Analysis In this study, the results of auto-refraction and subjective refraction were compared in different crystalline lens conditions. We compared the sphere and spherical equivalent (SE) of the refraction obtained by the two methods, and vectors analysis was performed to compare the cylindrical power[19-21]. According to vector analysis, astigmatism consists of two orthogonal vectors known as J_0 and J_{45}. The J_0 and J_{45} represent the horizontal/vertical and oblique components of astigmatism, respectively. These vectors are calculated based on the following equations:

$J_0=(-C/2)\cos(2\alpha)$

$J_{45}=(-C/2)\sin(2\alpha)$

Where C=cylinder power, α=axis of astigmatism.

The paired *t*-test was applied to compare the spherical error, SE, cylinder power, J_0, and J_{45} between the two methods. The Bland-Altman plots with 95% limits of agreement (LoA) were used to evaluate the agreement between the two methods. In the Bland-Altman graph, the mean values of refractive parameters (sphere, cylinder power, SE, J_0, and J_{45}) were plotted on the horizontal axis and the differences of the methods in these parameters were plotted on the vertical axis. The 95%LoA was calculated as the mean±1.96×standard deviation (SD) of the difference between the methods.

RESULTS

Of 3791 individual invitees, 3310 (response rate: 87.3%) participated in this study. After applying the exclusion criteria, the final analysis was performed on 5641 eyes of 2923 individuals. The mean age of the study participants was 67.85±6.39y (60-95y), and 58.9% (1723) of them were female. The pure PSCs were excluded due to the small number of cases. Finally, 1986 normal eyes, 1315 pseudophakic eyes, 1484 eyes with nuclear cataract, 228 eyes with cortical cataract, and 628 eyes with mixed cataract were analyzed.

Table 1 shows the mean and the difference of refractive parameters obtained by the two methods according to the crystalline lens status. The mean sphere obtained by the auto-refraction was more hyperopic in all conditions, the minimum and maximum differences of sphere between auto-refraction and subjective refraction were related to pseudophakic eyes and eyes with cortical cataract, respectively. Although there was a statistically significant difference of sphere between the two methods in all crystalline lens conditions. The 95%LoA for the sphere measurements of the two methods in different crystalline lens conditions showed that eyes with mixed cataract had the worst agreement and the best agreement was related to the pseudophakic eyes. Figure 1 illustrates the Bland-Altman plots for the agreement of the two methods in measuring the sphere according to the crystalline lens status. Regarding the SE, the results were similar to the spherical component.

As shown in Table 1, the mean cylinder power obtained by the auto-refraction was higher than that of the subjective refraction cylinder power in all crystalline lens conditions. The highest and lowest differences between the two methods regarding the cylinder power were observed in eyes with cortical cataract and normal eyes, respectively. As shown in Figure 2, the worst 95%LoA between the two methods in measuring the cylinder power was related to the eyes with mixed cataract (95%LoA: -0.44 to 0.96). Regarding the J_0, the mean values of J_0 obtained by auto-refraction were tended more toward against the rule direction in all crystalline lens conditions, and the two methods had the greatest difference in cortical cataract cases. Regarding the J_{45}, the lowest and highest differences and dispersion were observed in normal eyes and eyes with cortical cataract, respectively.

Table 2 shows the grouping of severities of the difference between the two auto-refraction and subjective methods by lens conditions.

DISCUSSION

The present study is the first large population-based study in the elderly above 60 years of age to compare the results of auto-refraction with subjective refraction in various crystalline lens conditions including non-cataractous phakic, different types of cataracts, and pseudophakia. The findings of the present study indicated that in the non-cataractous phakic elderly, the auto-refraction results were comparable to the subjective refraction only in the oblique component of the cylindrical refraction. Regarding the other refractive components including the sphere, the cylinder power, and the horizontal/vertical components of the cylindrical refraction, there was both a significant difference and a low agreement between the two

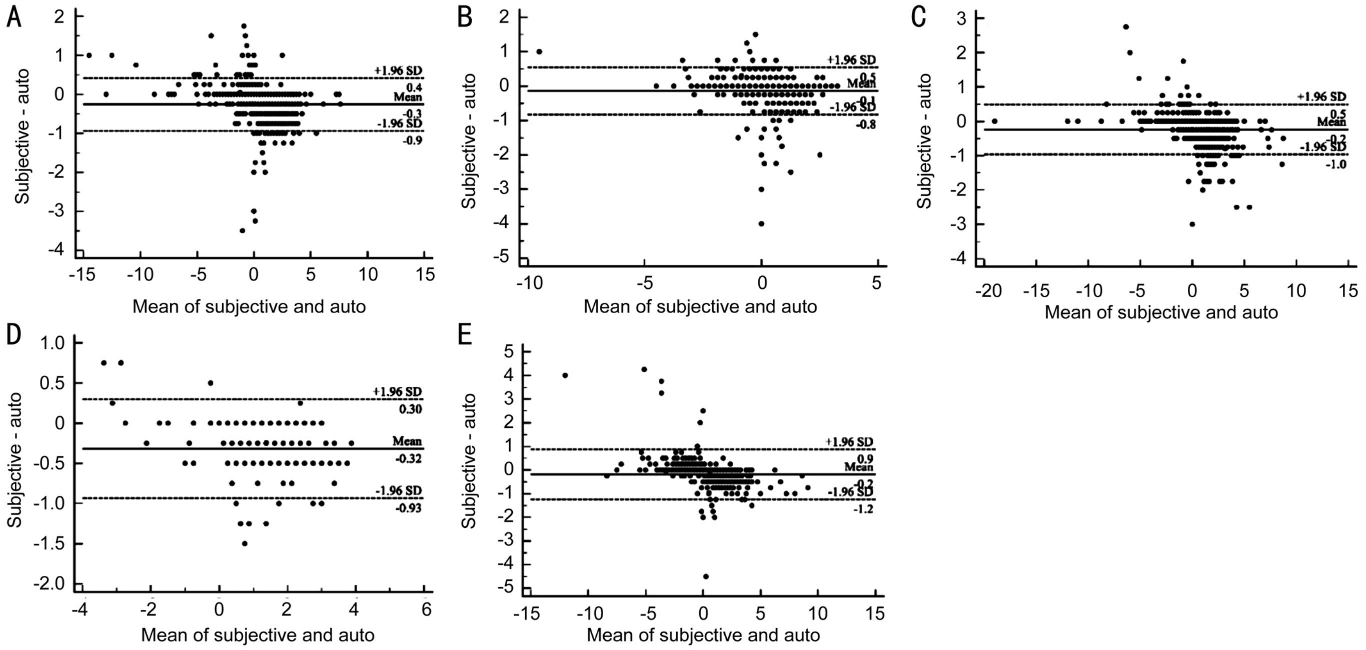

Figure 1 Bland-Altman plots for the agreement of the two methods in measuring the sphere according to the crystalline lens status A: Normal; B: Pseudophakic; C: Nuclear; D: Cortical; E: Mix.

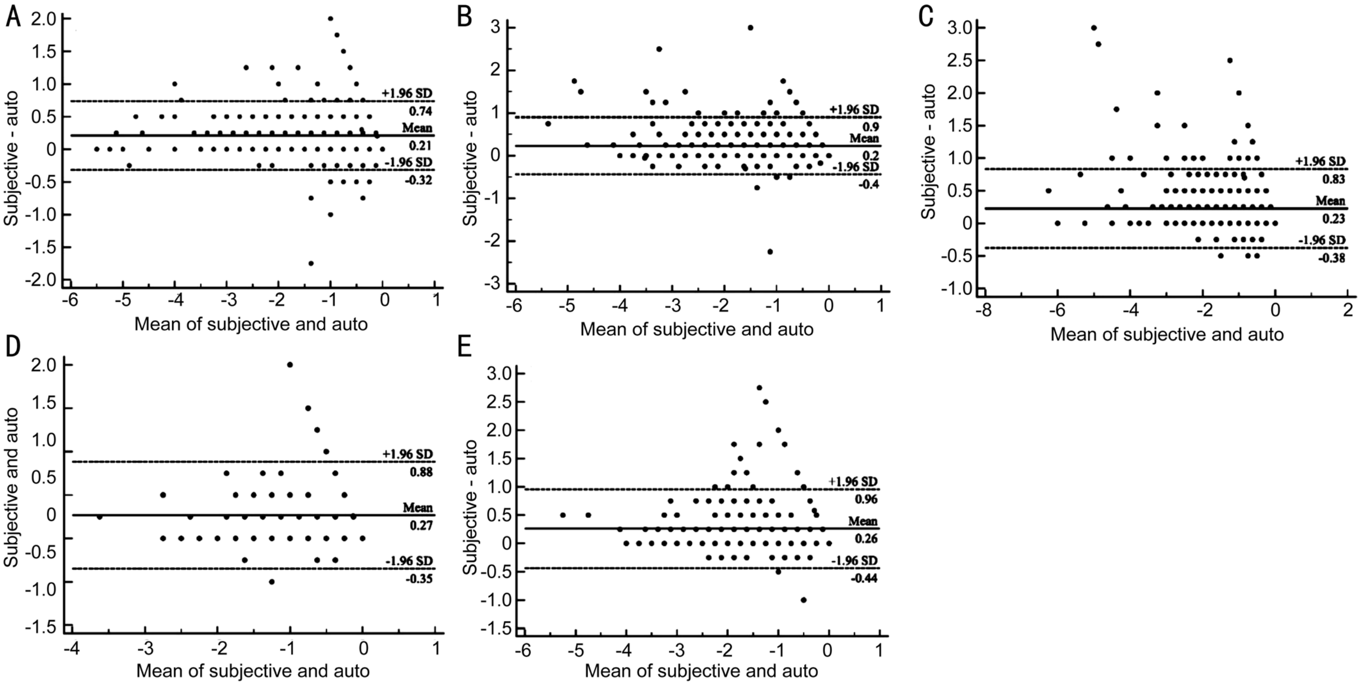

Figure 2 Bland-Altman plots for the agreement of the two methods in measuring cylinder power for different crystalline lens conditions A: Normal; B: Pseudophakic; C: Nuclear; D: Cortical; E: Mix.

methods. Most previous similar studies have been performed in children and adolescents. However, the discrepancy between the results of non-cycloplegic auto-refraction and subjective refraction has been reported in many of these studies[1,4,6,8,25-27]. A study was conducted by Choong *et al*[16] in children to compare the results of subjective refraction with auto-refraction in both cycloplegic and non-cycloplegic conditions. The results of that study showed that the results of auto-refraction agreed with the subjective refraction only after cycloplegia. In non-cycloplegic conditions, the results of the two methods were significantly different due to the over-minus error occurring in auto-refraction[16]. The studies by Bamdad *et al*[25] (age range 19-57y), Hashemi *et al*[1] (age range: 5-92y), and Farook *et al*[28] (age: 21y) also pointed out the inconsistency of subjective refraction with non-cycloplegic auto-refraction data and emphasized the importance of cycloplegia for auto-refraction. However, some other studies, such as the study by Bennett *et al*[15] (age range: 21-58y) reported similar and interchangeable results obtained by the subjective refraction and non-cycloplegic auto-refraction.

Table 1 Components of the astigmatism measured with subjective refraction versus auto-refraction in different phakic and pseudophakic

mean±SD

Lens condition	*n*	Subjective	Auto-refraction	Difference	*P*	95%LoA
Sphere						
Normal	1986	0.62±1.41	0.88±1.52	-0.26±0.35	<0.001	-0.94 to 0.42
Pseudophakic	1315	0.14±0.84	0.28±0.94	-0.14±0.35	<0.001	-0.83 to 0.54
Nuclear	1484	0.66±1.66	0.89±1.79	-0.24±0.37	<0.001	-0.97 to 0.49
Cortical	228	0.95±1.14	1.27±1.22	-0.32±0.31	<0.001	-0.93 to 0.3
Mix	628	0.51±1.91	0.69±2.15	-0.18±0.54	<0.001	-1.24 to 0.87
Cylinder						
Normal	1986	-0.7±0.74	-0.91±0.72	0.21±0.27	<0.001	-0.32 to 0.74
Pseudophakic	1315	-0.95±0.81	-1.18±0.82	0.23±0.34	<0.001	-0.44 to 0.9
Nuclear	1484	-0.78±0.78	-1.01±0.8	0.23±0.31	<0.001	-0.38 to 0.83
Cortical	228	-0.71±0.67	-0.98±0.62	0.27±0.31	<0.001	-0.35 to 0.88
Mix	628	-0.88±0.85	-1.14±0.84	0.26±0.36	<0.001	-0.44 to 0.96
SE						
Normal	1986	0.28±1.47	0.43±1.58	-0.15±0.34	<0.001	-0.82 to 0.51
Pseudophakic	1315	-0.34±0.82	-0.31±0.91	-0.03±0.35	0.005	-0.72 to 0.66
Nuclear	1484	0.26±1.69	0.39±1.81	-0.12±0.35	<0.001	-0.81 to 0.56
Cortical	228	0.6±1.19	0.78±1.26	-0.18±0.3	<0.001	-0.78 to 0.41
Mix	628	0.06±1.98	0.12±2.24	-0.05±0.57	0.022	-1.17 to 1.06
J_0						
Normal	1986	-0.15±0.41	-0.19±0.46	0.04±0.15	<0.001	-0.26 to 0.34
Pseudophakic	1315	-0.2±0.49	-0.23±0.56	0.03±0.18	<0.001	-0.33 to 0.39
Nuclear	1484	-0.19±0.45	-0.24±0.51	0.04±0.16	<0.001	-0.27 to 0.36
Cortical	228	-0.18±0.37	-0.23±0.43	0.05±0.17	<0.001	-0.28 to 0.38
Mix	628	-0.21±0.49	-0.26±0.56	0.05±0.18	<0.001	-0.31 to 0.42
J_{45}						
Normal	1986	0.01±0.26	0±0.29	0±0.11	0.454	-0.21 to 0.22
Pseudophakic	1315	0±0.34	0±0.39	0±0.14	0.910	-0.28 to 0.28
Nuclear	1484	0±0.26	0±0.31	0±0.12	0.925	-0.23 to 0.23
Cortical	228	0.02±0.26	0.03±0.31	-0.01±0.12	0.213	-0.24 to 0.22
Mix	628	-0.01±0.3	-0.01±0.35	0±0.14	0.757	-0.27 to 0.27

SE: Spherical equivalent; LoA: Limits of agreement.

The reason for the differences of the sphere and the SE values between the two methods in the present study could not certainly be the accommodation-related over-minus error mentioned in previous studies. It should be noted that the auto-refraction results were over-plus compared to the subjective refraction; this finding negates the role of accommodation. In addition, there is no ocular accommodation at these ages to cause an over-minus error[18,29]. There are two possible reasons for the difference between auto-refraction and subjective refraction results. The second possible reason may be that spherical ametropia in the elderly above 60 years of age is mainly hyperopic[30-32] and patients usually accept less hyperopic refraction in subjective refraction than that obtained in objective refraction[33]; this could be a possible reason for the underplusing of subjective findings. In general, due to the significant difference and wide LoA between the two methods in measuring spherical component, the use of these two methods interchangeably in non-cataractous phakic elderly is not recommended.

According to the findings found in the non-cataractous phakic group, the cylinder power obtained in auto-refraction was overestimated compared to the subjective refraction, and the two methods had a low agreement in measuring the cylinder power. The low inter-methods agreement was also found for the vectors J_0 and J_{45}. Although the J_{45} vector did not show a significant difference between the two refraction procedures, the LoA was wide and therefore, auto-refraction does not seem to be in good agreement with subjective refraction in the measurement of astigmatism. Reports from most previous studies also confirm that auto-refractometers do not conform to the standard gold subjective refraction in measuring cylinder, and this is evident in all age groups[28,34]. Given that this finding

Table 2 Severities of the difference between the two auto-refraction and subjective methods by lens conditions % (*n*)

Lens condition	Differences between subjective and auto-refraction (D)								
	<-1.5	-1 to -1.5	-0.5 to -1	0 to -0.5	0	0 to 0.5	0.5 to 1	1 to 1.5	>1.5
Sphere									
Normal	0.4 (8)	0.5 (10)	9.3 (185)	52.6 (1044)	32 (635)	4.2 (84)	0.8 (15)	0.2 (4)	0.1 (1)
Pseudophakic	0.6 (8)	0.5 (6)	4.5 (59)	35.7 (469)	49.9 (656)	7.8 (103)	0.8 (11)	0.2 (3)	0
Nuclear	0.7 (11)	1.1 (16)	8.4 (124)	46.3 (687)	37.7 (559)	4.9 (73)	0.6 (9)	0.1 (2)	0.2 (3)
Cortical	0	1.8 (4)	10.1 (23)	63.2 (144)	2.19 (50)	2.2 (5)	0.9 (2)	0	0
Mix	0.8 (5)	1.6 (10)	6.5 (41)	43.6 (274)	36.6 (230)	8.9 (56)	1 (6)	0	1 (6)
Cylinder									
Normal	0.1 (1)	0	0.2 (3)	1.5 (29)	43.3 (860)	48.5 (964)	5.6 (112)	0.8 (15)	0.1 (2)
Pseudophakic	0.1 (1)	0	0.1 (1)	1.5 (20)	47 (618)	42 (552)	6.6 (87)	2.2 (29)	0.5 (7)
Nuclear	0	0	0	1.2 (18)	45.2 (671)	45.3 (672)	7 (104)	0.9 (13)	0.4 (6)
Cortical	0	0	0	1.8 (4)	3.6 (82)	53.9 (123)	6.1 (14)	1.8 (4)	0.4 (1)
Mix	0	0	0.2 (1)	1.6 (10)	40.9 (257)	47.1 (296)	7.6 (48)	1.3 (8)	1.3 (8)
SE									
Normal	0.4 (7)	0.3 (6)	5.8 (116)	51.3 (1019)	26.5 (526)	13.5 (269)	1.7 (34)	0.3 (5)	0.2 (4)
Pseudophakic	0.5 (7)	0.4 (5)	2.1 (28)	30.6 (403)	38.3 (504)	24.6 (323)	2.4 (32)	0.8 (11)	0.2 (2)
Nuclear	0.4 (6)	0.3 (5)	5.9 (87)	44.7 (664)	31.8 (472)	14.8 (220)	1.4 (21)	0.4 (6)	0.2 (3)
Cortical	0	0.4 (1)	7.9 (18)	57.5 (131)	22.4 (51)	9.6 (22)	2.2 (5)	0	0
Mix	0.3 (2)	1.3 (8)	5.7 (36)	39 (245)	29.6 (186)	18 (113)	4.5 (28)	0.3 (2)	1.3 (8)

SE: Spherical equivalent.

has been reported in all age groups, it is probably due to the low accuracy of auto-refractometers[1,9]. Of course, more specialized studies are needed, especially with aberrometric devices to find out the definite cause.

A novel aspect of the present study is to compare the auto-refraction and subjective refraction methods in different ocular media conditions. The important point that can be deduced from the findings is that in all phakic and pseudophakic conditions, the sphere measured by auto-refraction had an over-plus error compared to subjective refraction and the lowest difference was seen in pseudophakic individuals. However, due to the wide LoA between the two methods in all cases, these two methods cannot be used interchangeably in the evaluation of sphere in any case. Another interesting point is that the 95%LoA of the sphere was significantly wider in mixed cataract than in other cases. Therefore, in this case, one should not rely on auto-refraction data. This low agreement in mixed cataract is probably related to the reduced precision of auto-refractometer measurements in conditions of widespread crystalline lens' opacity, which causes measurement error[21].

According to the results of the present study, the agreement findings for cylinder power as well as astigmatism components in pseudophakia and different types of cataracts were similar to the results found in non-cataractous phakic individuals discussed above. Therefore, it can be concluded that in individuals with pseudophakic condition and cataracts, the cylindrical findings of auto-refraction do not correspond well to the subjective findings. Since this type of comparison is not available in the elderly population in previous studies, it is not possible to compare the results.

As with some similar studies, there was an inherent limitation in the present study; various refractive values may be obtained across different pupillary positions in a cataractous patient. The part of the crystalline lens that was the origin of measurement in the objective refraction may not be the origin of subjective refraction and the patient might look at the chart from another lens point. However, we tried to position the participant's head in both the objective and subjective methods steady in the primary position to minimize this error.

In conclusion, the auto-refractometer/keratometer Nidek ARK-510 results in the elderly above 60 years of age with different phakic (cataractous or non-cataractous) and pseudophakic conditions do not correspond well with subjective refraction findings and these two methods are not interchangeable statistically. The difference between the two devices is also notable from clinical point of view and should be taken into consideration. This discrepancy in spherical findings is more pronounced in individuals with mixed cataract than in other cases. Therefore, it is recommended that auto-refraction data alone should not be used as a basis for clinical prescribing and epidemiological studies in the elderly. The auto-refraction data can be used as a starting point for subjective refraction and it is better to perform subjective refraction in any case.

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