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Use of refractive aids among adults in a general population

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Spectacles and contact lenses are important for conducting a normal life in a large part of the general population. The purpose of this study was to estimate the use of these refractive aids in a normal adult population, and to identify characteristics of persons who should be targeted in order to improve uncorrected refraction. In the FORSYN study, 10,350 citizens representative for the adult Danish population were invited for a non-cycloplegic eye examination. The examination was completed in 3,384 persons, and the data were adjusted to represent the frequencies in the originally invited population on the basis of age, sex and socio-economic factors. The frequencies were projected to estimates of absolute numbers in the total adult Danish population. Refractive aids were used by 72.6%, 95% CI: 71.7-73.5% of the adult population. Distance correction was used by 55.7% (95% CI: 54.8-56.7%), contact lenses alone or alternating with spectacles by 11.2% (95% CI: 10.6-11.8%) and reading glasses by 18.8% (95% CI: 18.0-19.5%). Uncorrected refractive error resulted in a reduction in distance visual acuity of 2.99 ETDRS letters per diopter of hyperopia and of 10.3 ETDRS letters per diopter myopia ($p < 0.0001$ for both regressions). Uncorrected refractive error reduced distance visual acuity significantly in persons using single vision spectacle lenses and progressive addition spectacle lenses that had been prescribed more than 3 years previously. Refractive aids were used in approximately 72% of the population and should be checked when more than 3 years have passed since the last visit with a dispensing optometrist.

Keywords Refractive aids, Population study, Habitual correction, Autorefraction, Subjective refraction.

Spectacles and contact lenses are important for conducting a normal life in a large part of the general population[1,2], and can only in selected cases be replaced by refractive surgery on the cornea or the lens[3–5]. Refractive correction by spectacles or contact lenses can compensate for ametropia and presbyopia, and may help magnifying objects for persons with low vision. However, the refractive corrections require regular adjustments to compensate for wear and changes in refraction that occur over time[6,7]. The regular updates are not always achieved, which is evidenced by studies showing that uncorrected refractive error is a frequent cause of visual impairment[8,9]. This is a particular challenge for persons entering nursing homes and for visually impaired persons where the level of activity and rehabilitation to a large extent depends on vision[10]. However, the prevalence of different types of refractive aids and optical characteristics of the persons in need for updating of these aids in a general population have not been studied in detail.

In the FORSYN study 10,350 citizens representative for the Danish population were invited for a non-cycloplegic eye examination that included questioning about the use of optical corrections, measurement of autorefraction, habitual correction and optimal subjective refraction[11]. On the basis of age, sex and socio-economic parameters registered in Statistics Denmark, the data were subsequently corrected for selection bias in order to become representative for the general population. The present study reports the prevalence in the use of spectacles and contact lenses, and identifies characteristics of persons who should be in order to improve uncorrected refractive error.

Methods

Study design

The design and execution of the FORSYN study has been described in detail previously[11]. In short, 10,350 persons living within 40 km from Aarhus University Hospital were selected by Statistics Denmark to represent the adult Danish population aged 18 years or older with respect to age (mean = 49.2 years, SD = 19.2 years, range: 18.0–102.2 years), sex (5,110 men and 5,240 women) and socio-economic parameters. These persons

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were invited for a non-mydriatic eye and non-cycloplegic examination at the Department of Ophthalmology, Aarhus University Hospital.

Examination

The examinations were carried out by two skilled optometrists between 1. February 2020 and 30. June 2022[11]. The examined persons were questioned about previous systemic and ocular diseases including cataract and refractive surgery, use of refractive aids, and the time since the last examination performed by a dispensing optometrist. Subsequently, an examination was performed in both eyes starting with the right eye. The examination included measurement of habitual correction using a lensmeter (SL600P, Nidek, Gamagori Aichi, Japan), autorefraction (Tonoref II, Nidek, Gamagori Aichi, Japan), and optimal subjective correction using a phoropter (Haag Streit Visutron 900+, Möller-Wedel Optical, Wedel, Germany). In order to study how uncorrected refractive error affected vision, monocular visual acuity at distance was measured using charts that complied with the Early Treatment for Diabetic Retinopathy (ETDRS) standard[12], and measurements were carried out without correction, with habitual correction and with optimal subjective correction. All data, including information about age, sex, and previous cataract surgery were registered in a database and saved on a secure server for later analysis.

Data analysis

The examination programme was completed in 3,384 of the persons who accepted participation and showed up for the examination. The identities of these persons were returned to Statistics Denmark that calculated weights to allow an extrapolation of data to the original population representative sample of 10,350 citizens. The calculation of weights was based on age, gender, educational level, personal income, marital status, family income and number of children, occupational basis for income, country of origin, and degree of urbanisation at the home address. The calculation used the Generalized Regression Estimator (GREG) in order to include multiple variables and the CLAN programme developed by Statistiske Centralbyrån (Statistics Sweden) to be used with the statistical analysis system SAS® (Cary, North Carolina, USA)[11]. The calculated weights were subsequently returned to the authors.

All statistical analyses by the authors were performed in STATA (version 14.2, StataCorp, Texas, USA), and the sample of studied persons were expanded to represent the original sample using STATA's "expand weight" command. This resulted in 10,458 observations that were representative for the total population.

For each observation the reported time (t) since the last visit with a dispensing optometrist was allocated to one of the following categories (t in years), 1: $t<1/2$, 2: $1/2\leq t<1$, 3: $1\leq t<2$, 4: $2\leq t<3$, 5: $3\leq t$. The participants were also allocated to one of four age groups (in years), i.e., 1: $18\leq$ Age <40, 2: $40\leq$ Age <60, 3: $60\leq$ Age <80, 4: $80\leq$ Age.

The type of habitual distance correction was noted as none, single vision (monofocal), bifocal, trifocal, or progressive addition spectacle lenses, or as contact lenses. Alternative corrections were noted to be present when contact lenses were used in one eye and spectacles on the other eye, or when corrections were used for other distances, such as reading spectacles or computer spectacles. The spherical equivalents of refraction were calculated by adding half of the power of the regular astigmatism to the spherical power.

The expanded population representative frequencies of the use of corrective aids (with 95% CI intervals) were projected to the total population using the F-distribution based on the binomial standard error[13], where it was assumed that the adult Danish population by January 1. 2020 consisted of 4,666,600 persons as reported by Statistics Denmark (www.dst.dk). The lower level of detection of a given condition could thereby be calculated to be 445 cases in the total population[11].

Two-sample test for a proportion (z-test) was used to test for differences in the use of corrective aids among men and women. One-way ANOVA was used to test for differences between the spherical equivalent of habitual refraction, autorefraction, and optimal subjective refraction for each type of refraction in each eye, which was followed by post-hoc analysis using t-tests on all combinations of two means with Bonferroni's corrections for multiple comparisons.

Multiple linear regression was performed with sex, age, autorefraction, and the difference between habitual and optimal subjective correction as covariates and visual reduction as the dependent factor for persons with both hyperopic and myopic habitual correction. The regressions were performed with inverse probability weighting of the variables so that confidence intervals were corrected according to the number of participants[14].

Results

Altogether 7,592/10,458 persons corresponding to 72.6%, 95% CI: 71.7-73.5% of the expanded population representative sample used a refractive aid, either habitually (for full-time wear) or alternating at specific distances or purposes.

Table 1 shows the expanded population representative numbers, the percentages of the total adult population and the age-specific percentages of adults using different types of distance correction or none. Among the expanded population representative 1,678 persons who used single vision spectacles, three persons used this correction on one eye and no correction on the other eye. Among the expanded population representative 3,326 persons who used progressive addition spectacle lenses, eight persons used this correction on one eye and no correction on the other eye and eight persons on one eye combined with single vision spectacle lenses on the other eye. Two persons using trifocal glasses have for simplicity been included in the group using bifocal glasses to amount to 111 persons for this group. Finally, among the expanded population representative 695 persons who used contact lenses 44 were in one eye only. Significantly more women (4,088/7,592 = 53.8%) than men (3,504/7,592 = 46.2%) used any correction ($p<0.0001$). Cataract surgery had been performed in at least one eye in 968/10,458 = 9.3% of the persons among which significantly more used bifocal or progressive addition

Primary distance correction						
	Age group	18 ≤ Age < 40 years	40 ≤ Age < 60 Years	60 ≤ Age < 80 years	80 ≤ Age years	18 ≤ Age years
Single vision	Adjusted number	788	522	297	89	1696
	Percentages of all adults	7.5% (7.0–8.1%)	5.0% (4.6–5.4%)	2.8% (2.5–3.2%)	0.9% (0.7–1.1%)	16.2% (15.5–16.9%)
	Age specific percentage	23.9% (22.5–25.4%)	15.0% (13.8–16.2%)	9.6% (8.6–10.7%)	15.4% (12.5–18.6%)	–
Bifocal	Adjusted number	0	28	27	56	111
	Percentages of all adults	0%	0.3% (0.2–0.4%)	0.3% (0.2–0.4%)	0.5% (0.4–0.7%)	1.1% (0.9–1.3%)
	Age specific percentage	0%	0.8% (0.5–1.2%)	0.9% (0.6–1.3%)	9.7% (7.4–12.4%)	–
Progressive addition	Adjusted number	36	1016	1972	302	3326
	Percentages of all adults	0.3% (0.2–0.5%)	9.7% (9.2–10.3%)	18.9% (18.1–19.6%)	2.9% (2.6–3.2%)	31.8% (30.9–32.7%)
	Age specific percentage	1.1% (0.8–1.5%)	29.2% (27.7–30.7%)	63.5% (61.8–65.2%)	52.2% (48.0–56.3%)	–
Contact lenses	Adjusted number	330	301	64	0	695
	Percentages of all adults	3.2% (2.8–3.5%)	2.9% (2.6–3.2%)	0.6% (0.5–0.8%)	0%	6.7% (6.2–7.1%)
	Age specific percentage	10.0% (9.0–11.1%)	8.7% (7.8–9.6%)	2.1% (1.6–2.6%)	0%	–
No refractive aid	Adjusted number	2138	1616	744	132	4630
	Percentages of all adults	20.0% (19.7–21.2%)	15.5% (14.8–16.2%)	7.1% (6.6–7.6%)	1.3% (1.1–1.5%)	44.3% (43.3–45.2%)
	Age specific percentage	65.0% (63.3–66.6%)	46.4% (44.7–48.1%)	24.0% (22.5–25.5%)	22.8% (19.4–26.4%)	–
Total	Adjusted number	3292	3483	3104	579	10,458
	Percentages of all adults	31.5% (30.6–32.4%)	33.3% (32.4–34.2%)	29.7% (28.8–30.6%)	5.5% (5.1–6.0%)	–
	Age specific percentage	100%	100%	100%	100%	–

Table 1. The numbers in the expanded population representative sample ($n = 10458$), the percentage of adults (mean, 95% CI) and the age-specific percentage (mean, 95% CI) of adults using different types of distance correction.

	Age group	18 ≤ Age < 40 years	40 ≤ Age < 60 Years	60 ≤ Age < 80 years	80 ≤ Age years	Total
Alternative distance correction						
Glasses instead of contact lenses	Expanded number	252	230	40	0	522
	Percentages of all adults	2.4% (2.1–2.7%)	2.2% (1.9–2.5%)	0.4% (0.3–0.5%)	0%	5.0% (4.6–5.4%)
	Age specific percentage	7.7% (6.8–8.6%)	6.6% (5.8–7.5%)	1.3% (0.9–1.8%)	0%	
Contact lenses instead of glasses	Expanded number	258	182	32	4	476
	Percentages of all adults	2.5% (2.2–2.8%)	1.7% (1.5–2.0%)	0.3% (0.2–0.4%)	0.04% (0.0–0.1%)	0.8% (0.6–0.9%)
	Age specific percentage	7.8% (6.9–8.8%)	5.2% (4.5–6.0%)	1.0% (0.7–1.5%)	0.7% (0.2–1.8%)	
Correction for other distances						
Reading glasses	Expanded number	175	959	686	142	1962
	Percentages of all adults	1.7% (1.4–1.9%)	9.2% (8.6–9.7%)	6.6% (6.1–7.1%)	1.4% (1.1–1.6%)	18.8% (18.0–19.5%)
	Age specific percentage	5.3% (4.6–6.1%)	27.5% (26.1–29.1%)	22.1% (20.7–23.6%)	24.5% (21.1–28.2%)	
Computer glasses	Expanded number	77	109	30	0	216
	Percentages of all adults	0.7% (0.6–0.9%)	1.0% (0.9–1.3%)	0.3% (0.2–0.4%)	0%	2.1% (1.8–2.4%)
	Age specific percentage	2.3% (1.9–2.9%)	3.1% (2.6–3.8%)	1.0% (0.7–1.4%)	0%	

Table 2. The numbers in the expanded population representative sample ($n = 10458$), the percentage of adults (mean, 95% CI) and the age-specific percentage of adults (mean, 95% CI) using alternating distance correction (upper part) and separate correction for near purposes (lower part).

spectacle lenses and significantly less used single vision correction, contact lens or no distance correction than in the non-operated group when corrected for age ($p < 0.0001$ for all comparisons).

Table 2 shows the expanded population representative numbers, the percentages of the total adult population and the age-specific percentage of adults using alternative corrections for distance or near purposes. It appears that 522/695 (75.1%) who primarily used contact lenses for distance alternated with spectacles whereas 476/5133 (9.3%) who primarily used spectacles for distance alternated with contact lenses.

This implied that contact lenses were used as habitual or alternative correction in altogether 1,171 persons in the expanded population representative sample corresponding to 11.2% (95% CI: 10.6-11.8%) of the population, of which significantly more ($p < 0.001$) were women (740/1,171 = 63.2%) than were men (431/1,171 = 36.8%). Among the persons who used contact lenses 12/1,171= (1.0%) used rigid lenses and 59/1,171 (5.0%) used multifocal lenses. The use of reading glasses and computer glasses were most frequent among persons at working age with presbyopia (40–60 years).

Table 3 shows the spherical equivalent of the habitual correction, autorefraction, and optimal subjective refraction in the two eyes for persons using different types of distance correction. Single vision spectacles and contact lenses on average corrected more myopic eyes, whereas bifocal and progressive addition spectacles on average corrected more hyperopic eyes. It also appears that persons who used single vision spectacle lenses had significantly larger negative autorefraction than habitual and optimal subjective correction in both eyes.

In the persons who used bifocal lenses, both autorefraction and optimal subjective refraction was significantly more positive than habitual correction in the left eye. In the persons who used progressive addition spectacle lenses, optimal subjective refraction was significantly more positive than autorefraction which was again significantly more positive than habitual correction. A similar pattern was observed in the left eye, except for a lack of significant difference between optimal subjective refraction and autorefraction. For the persons who used contact lenses, the habitual correction was significantly less negative than autorefraction and optimal subjective refraction in both eyes In persons not using distance correction, optimal correction was less positive than autorefraction in both eyes.

Figure 1 shows the change in distance visual acuity as a function of under-correction (optimal subjective minus habitual refraction) in the eye where this difference was largest positive ($n = 1,510$). The slope of the curve is 2.99 ETDRS letters per diopter ($p < 0.0001$) and the average spherical equivalent of autorefraction (mean ± SD) 0.56 ± 2.09. Multiple linear regression showed that autorefraction, sex, and the power of regular astigmatism had no significant contribution to the change in distance visual acuity ($p > 0.23$ for all parameters). However, age and more than 3 years since the last visit with a dispensing optometrist in persons who used progressive addition spectacle lenses ($p < 0.0001$ for both comparisons) contributed significantly to the reduction in distance visual acuity. The time since the last visit with an optometrist showed no contribution to the reduction in distance visual acuity for the other correction types ($p > 0.23$ for all comparisons).

Figure 2 shows the change in distance visual acuity as a function of under-correction (optimal subjective minus habitual refraction) in the eye where this difference was ($n = 591$). The slope of the curve is -10.3 ETDRS letters per diopter ($p < 0.0001$), and the average spherical equivalent of autorefraction (mean ± SD) -1.04 ± 3.07. Multiple linear regression showed that age, sex, and the power of regular astigmatism had no significant contribution to the change in refraction ($p > 0.55$ for all comparisons). However, less negative power of autorefraction and a time of more than 3 years since the last visit with a dispensing optometrist in persons who used both single vision and progressive addition spectacle lenses contributed significantly to the reduction in distance visual acuity ($p < 0.01$ for both comparisons). The time since the last visit with a dispensing optometrist showed no contribution to the reduction in distance visual acuity for the other correction types ($p > 0.57$ for all comparisons).

Discussion

The present study shows a prevalence of the use of glasses or contact lenses in the Danish population which is at about the same order of magnitude as reported in a survey from 2005[1], but extends these findings by providing a more detailed account of the use and need for adjustment of different types of refractive aids representing the total adult population. The examinations were performed by two optometrists who used identical procedures and supervised each other regularly in order to obtain comparable recordings.

	Right					Left				
	Habitual	**Auto**	**Optimal**	**Difference (n)**	**p**	**Habitual**	**Auto**	**Optimal**	**Difference (n)**	**p**
Single vision	− 1.19 ± 2.16	− 1.29 ± 2.55		0.10 ± 1.19 (1664)	0.002	− 1.12 ± 2.14	− 1.21 ± 2.33		0.09 ± 0.69 (1677)	< 0.0001
	− 1.21 ± 2.16		− 1.20 ± 2.27	0.01 ± 0.54 (1680)	1.00	− 1.13 ± 2.14		− 1.15 ± 2.27	− 0.02 ± 0.57 (1682)	0.45
		− 1.30 ± 2.54	− 1.19 ± 2.29	0.11 ± 1.07 (1674)	< 0.0001		− 1.22 ± 2.32	− 1.15 ± 2.27	0.06 ± 0.44 (1687)	< 0.0001
Bifocal	0.54 ± 1.85	0.56 ± 1.97		− 0.03 ± 0.73 (108)	1.00	0.65 ± 1.86	1.20 ± 3.06		− 0.54 ± 1.94 (111)	0.01
	0.54 ± 1.85		0.63 ± 1.85	0.01 ± 0.45 (108)	0.09	0.65 ± 1.86		1.26 ± 3.05	0.61 ± 1.95 (108)	0.006
		0.47 ± 0.19	0.53 ± 1.93	0.06 ± 0.55 (111)	0.78		1.11 ± 3.07	1.15 ± 3.07	0.04 ± 0.34 (108)	0.57
Progressive addition	0.13 ± 2.03	0.19 ± 2.49		− 0.06 ± 1.33 (3269)	0.03	0.16 ± 2.07	0.28 ± 2.45		− 0.13 ± 1.14 (3268)	< 0.0001
	0.13 ± 2.03		0.30 ± 2.11	0.16 ± 0.52 (3270)	< 0.0001	0.16 ± 2.08		0.31 ± 2.13	0.15 ± 0.45 (3268)	< 0.0001
		0.20 ± 2.47	0.30 ± 2.10	0.10 ± 1.21 (3317)	< 0.0001		0.29 ± 2.44	0.28 ± 2.43	0.03 ± 1.03 (3322)	0.33
Contact lens	− 2.32 ± 3.05	− 2.76 ± 3.51		0.44 ± 1.42 (654)	< 0.0001	− 2.25 ± 3.18	− 2.74 ± 3.36		0.49 ± 0.77 (650)	< 0.0001
	− 2.32 ± 3.05		− 2.66 ± 3.32	− 0.33 ± 0.82 (654)	< 0.0001	− 2.25 ± 3.18		− 2.75 ± 3.27	− 0.50 ± 0.73 (650)	< 0.0001
		− 2.53 ± 3.28	− 2.63 ± 3.48	0.09 ± 1.15 (695)	0.12		− 2.61 ± 3.31	− 2.62 ± 3.22	− 0.01 ± 0.33 (695)	0.78
No refractive aid	–	0.01 ± 0.69	− 0.06 ± 0.93	0.07 ± 0.57 (4604)	0.005	–	0.02 ± 0.70	− 0.001 ± 0.82	0.03 ± 0.43 (4592)	< 0.0001

Table 3. The spherical equivalent (Mean ± SD) of habitual correction, autorefraction and optimal subjective correction for different distance corrections (or none) in the two eyes in the expanded population representative sample ($n = 10458$). p-values refer to the t-tests corrected for multiple comparisons.

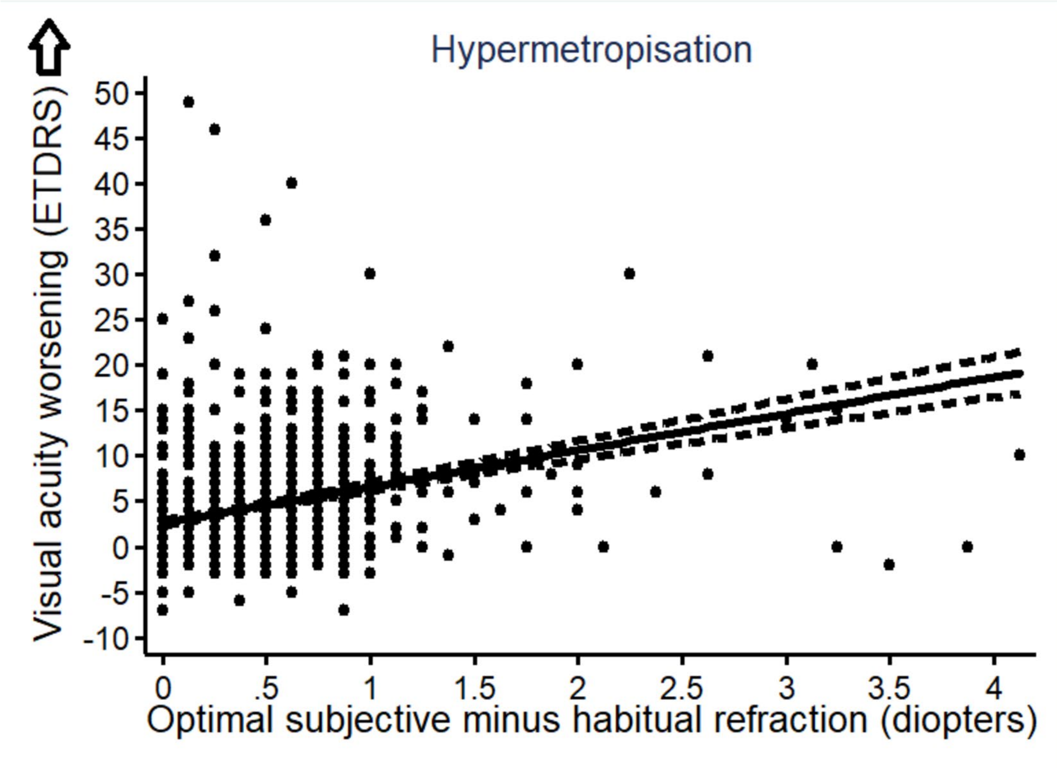

Fig. 1. The reduction in distance visual acuity as a function of optimal subjective subtracted by habitual refraction in the eye where this difference was largest positive.

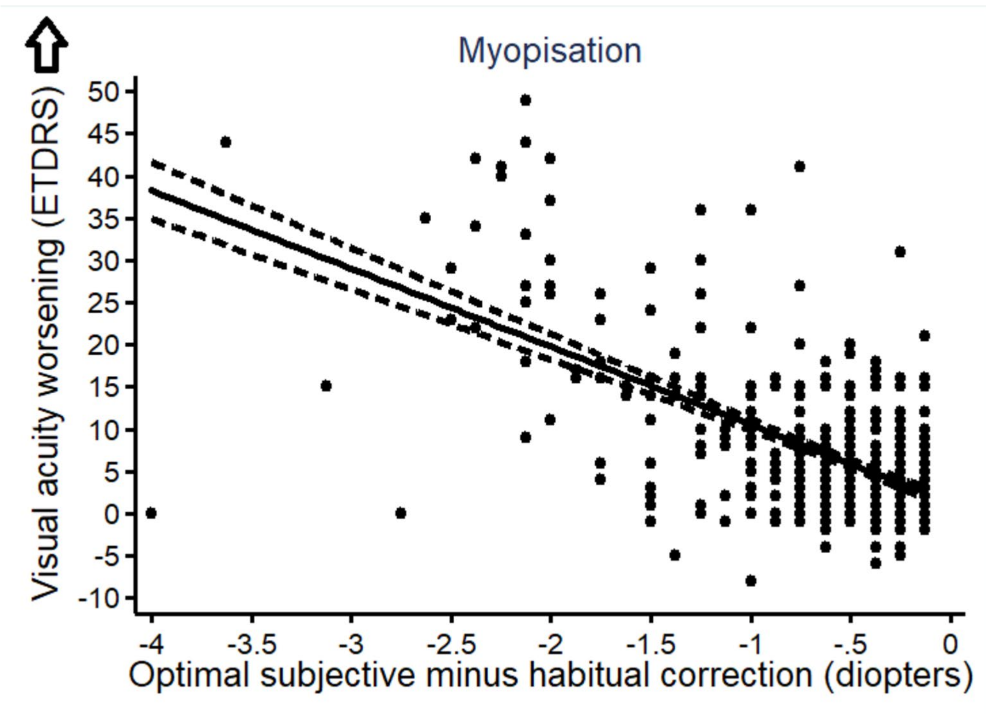

Fig. 2. The reduction in distance visual acuity as a function of optimal subjective subtracted by habitual refraction in the eye where this difference was largest negative.

In the Danish society, optical corrections are primarily paid by the citizens, and it cannot be excluded that this may in some cases be a limitation for providing such aids. This implies that the observed use of spectacles and contact lenses may underestimate the real need[1]. The observed use of refractive aids could be estimated to correspond to approximately 55% of the adult population using distance correction with or without incorporated near correction, and approximately 19% using separate reading correction which is in accordance with data from other countries[15]. The finding that significantly more women than men used distance correction confirms previous reports[1] and may be due to differences in following advice from health personnel, but it cannot be excluded that more near work or anatomical features such as shorter arms may have exhibited the consequences of presbyopia at an earlier age in women than in men[16]. This difference may have been exacerbated by a lower quality of the tear film among females than males[17].

The study showed that age was an important factor for the used type of refractive correction. In younger persons who can be expected to predominantly need correction for myopia, the most frequently used refractive aids were single vision spectacle lenses and contact lenses which is supported by the fact that these corrections predominantly had negative power. Conversely, in older persons the increasing need for near vision aids was evidenced by a reduced use of single vision spectacle lenses and contact lenses and an increased use of solutions with separate or inbuilt near correction such as progressive addition spectacle lenses and bifocal lenses[2]. These refraction types tended to have predominantly positive power which suggests a hyperopic shift with age due to a reduction of accommodation resulting from the non-cycloplegic refraction in the younger individuals[18]. Additionally, the less frequent use of contact lenses with age confirms previous reports and may be due to differences in habits for the older generations or discomfort because of an increasing sensation of dryness and irritation at the ocular surface[19].

Approximately one fifth of the persons above the age of 80 years used no distance correction which may partly be the result of emmetropisation secondary to cataract surgery. This interpretation is confirmed by the fact that all cataract operated persons in the study not using distance correction used reading glasses, and that the use of progression addition spectacle lenses and bifocal lenses was more frequent in cataract operated (516/968 = 53.3%) than in non-operated persons (2921/9490 = 30.8%).

The average autorefraction in persons not using optical correction was close to zero which can be assumed to be a consequence of a predominance of younger non-myopic individuals in this group. The significantly larger positive optimal subjective refraction and autorefraction than habitual refraction in the left eye of persons using bifocal and progressive addition spectacle lenses correction in the left than the right eye may be a result of the order of the examinations that were carried out of which the change in refraction may be a consequence of instrument myopia[20]. These differences among the two eyes should be considered in the interpretation of non-cycloplegic refraction values in clinical practice. The fact that the power of contact lenses was significantly lower than autorefraction and optimal non-cycloplegic refraction can be assumed to a consequence of the vertex distance compensation[21] and that users of contact lenses are younger with low degrees of astigmatism that may not be included in the refrative aid if it does not affect visual acuity[22].

The observation that habitual correction resulted in hyperopia in some participants and myopia in other participants might be related to changes in refraction that occur with age. Thus, hyperopisation might be due to insufficient inhibition of accommodation at the time of prescription of visual aids which becomes less apparent when accommodation decreases with age. The myopisation in other participants may have been intended because of a better patient comfort with habitual correction adjusted to a distance closer than infinity, but may also be due to a more frequent correction of the age-related increase in against-the-rule astigmatism with the consequent effects on visual acuity[22,23]. This should be investigated in a longitudinal study.

Figure 1 (lower right area) and 2 (lower left area) contain observations where apparent large additions in refraction to correct ametropia resulted in limited improvements in distance visual acuity. These cases represent participants with retinal or other diseases that reduce visual acuity to a level that cannot be improved substantially by optimising refraction. Similarly, in a number of cases large improvements in distance visual acuity were obtained with moderate improvements in refraction. These cases include participants where the corrected refractive error contained a considerable cylinder power.

The reduction in distance visual acuity was only approximately 3 ETDRS letters per diopter positive power, but approximately 10 ETDRS letters per diopter negative power in the refractive aid. This can be explained as consequence of accommodation among the younger persons that had partially compensated for hyperopia and explains that age was a significantly contributing co-variate to the change in visual acuity as a function of the degree of hyperopic correction error in this group. This also explains that age was not a significantly contributing co-variate to the change in visual acuity in the persons with myopic correction error. However, in this group less negative power was a significant contributing factor to the reduction in distance visual acuity which may potentially be due to differences in the vertex distance between the cornea and the correction lens when refraction is determined in the phoropter and with trial lenses. Additionally, a myopic shift of one diopter represents less retinal blur in already myopic (longer) eyes because of the inverse relation between refraction and focal length of the optical system.

In the present study 255 of the participants in the expanded population representative sample were found to be under-corrected by more than 0.5 diopter with a consequent reduction in distance visual acuity of more than 5 ETDRS letters that might benefit from an adjustment of the correction. This would correspond to 2.44% (95% CI: 2.15-2.75%) of the adult population. In the remaining part of the population the control programme followed by the citizens had ensured that refractive aids were sufficiently adjusted. This is in accordance with previous findings from the UK[9] and indicates that the found estimates of undiagnosed refractive errors may be relevant for Western countries more generally. The need for optimising a previously prescribed optical correction may be an indication of age-related changes that have not yet become symptomatic for the person, but the correction of which might potentially optimise vision.

The strength of the present study is the large sample size and the fact that data were adjusted for socio-economic factors to become representative for the general population. However, it was a main limitation that the examinations were performed without cycloplegia. This may have invalidated the values of some autorefractions and optimal subjective refractions in younger individuals, but on the other hand reflected the conditions of the population in everyday life.

It can therefore be concluded that approximately 72% of the studied population use a refraction aid. Refraction should be checked in persons who use single vision spectacle lenses or progressive addition spectacle lenses and in whom more than 3 years have passed since the last visit with a dispensing optometrist.

Data availability

The datasets generated and/or analysed during the current study are not publicly available due to restrictions from the Danish data protection law but are available from the corresponding author on reasonable request. Contact: Toke Bek, Department of Ophthalmology, Aarhus University Hospital, DK-8200 Aarhus N. e-mail: toke.bek@mail.tele.dk.

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Author contributions

All authors contributed to conceiving the study, analysing and interpreting data, and writing the manuscript. TB overviewed and contributed to the clinical examinations.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval
The study was approved by the Regional Scientific Ethics Committee (Ref 1-10-72-1-19) and the Regional Data Protection Office (Ref 1-16-02-419-19).

Participant consent
All procedures followed the declaration of Helsinki and the patients gave their oral and written informed consent to participate.

Additional information
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