ERRATUM

Prevalence of refractive conditions in the general population attending eye care clinics in the north of Portugal

In the article by A. Queirós, T. Ferrer-Blasco, J. Jorge, S. Peixoto de Matos, J.M. González-Méijome, A. Cerviño, R. Montés-Micó, that appeared on page 103 of the Atti della Fondazione Giorgio Ronchi, **64** (1), 101-111, 2009, it should be stated that approval for research project was obtained from an internal Review Board instead of the Ethics Committee of the School of Sciences (University of Minho) as erroneously mentioned in the Methods section.

Prevalence of refractive conditions in the general population attending eye care clinics in the north of Portugal

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ABSTRACT. – *Aim: The purpose of this study was to report the first estimations on the prevalence of refractive conditions in a Portuguese population attending several ophthalmologic and optometric clinics within the same region. Methods: Values of non-cycloplegic subjective refraction from the right eye of 4288 patients (40.08±18.75 years) were analyzed to estimate the prevalence of refractive conditions as a function of age and gender. The prevalence of anisometropia and presbyopic correction as a function of age and gender were also investigated. Results: Mean spherical equivalent refractive error was –0.29±2.01D. 29.8% of the patients had myopia, 45% had emmetropia and 25.2% had hyperopia. Young adults ranging from 20 to 35 years of age presented the highest prevalence of myopia. Conversely, the peak of hyperopic condition was for the oldest population. Anisometropia, defined as a difference in spherical equivalent equal or higher than 3D was present in 1.4% of our population. Conclusion: The prevalence of refractive conditions has been established for a large non-randomized sample of the Portuguese population for the first time. Important refractive changes were evidenced in the fifth decade of life, comprising an increase in the prevalence of hyperopia along with a shift in the amount of astigmatism. Although this study is not representative of the overall Portuguese population, there seem to be evidence that myopia could be increasing among the younger age groups.*

1. Introduction

Refractive error is the most common eye condition and its compensation with spectacles, contact lenses or refractive surgery plays important role in the health care activity of developed countries. According to current research reports,

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the prevalence of refractive errors seems to be increasing in most areas of the world what makes this subject a priority area in current optometric research.

Although comparisons of refractive error rates across studies could be limited by differences in definitions of dioptric limits for myopia, emetropia and hyperopia, measurement techniques, and sampled population (1, 2) we have currently a broad panel of recent studies which agree that the prevalence of refractive conditions seem to be changing towards myopization of youngest and young adult subjects, specially those submitted to particular situations of near work, ethnicity, and other environmental conditions. This is particularly evident in Asian countries (3-5) where the prevalence of myopia can reach 90% of the population. However, today it is also a matter of fact in European countries.

Several epidemiological studies have shown that genetic factors such as race and family history (6, 7), and environmental factors (8), such as education (9, 10), socioeconomic status and even region (11, 12),are important risk factors for myopia. A study of Shimuzu *et al.* (13) reported higher prevalence of myopia among younger subjects within a Japanese community of 2168 people between 40 and 79 years, with a significant influence of education levels and socioeconomic factors. Conversely, Jiménez *et al.* (14) found a surprisingly low prevalence of myopia among Amazon indigenous with little or no formal education.

Being hyperopia the most common refractive condition at birth with the exception of premature neonates, in the school age a general trend towards myopia is observed, with several structural changes mediating such alteration. While classical studies observed that refraction is fairly stable between 20 and 40 years of age current studies do not totally agree with such theory (15).

Reports on the prevalence of refractive conditions comprising larger samples have been recently published. In the eastern part of Spain, Montés-Micó and Ferrer-Blasco, found a prevalence of myopia of about 21% in the general population attending optometric clinics (16). Wensor, in Australia found a slightly lower prevalence, with 17% for subjects above 40 years old (11). Age of patients in different data collections are a main drawback to allow comparisons among countries.

To the best of our knowledge the only data on the prevalence of refractive conditions in Portugal were reported by Jorge et al on a population of 199 young-adult university students under cycloplegia; 20% of the sample had myopia, 38.5% had emmetropia and 41.5% had hyperopia (17).

With the present study we attempt to characterize the distribution of refractive error by gender and age, and presbyopic correction and the prevalence of anisometropia in the North of Portugal.

2. Methods

The files of 4288 patients attending five ophthalmologic and four optometric clinics in the North of Portugal (Region of Minho) from 1999 until 2004 were

reviewed in order to collect age, gender and distance and near prescriptions of a heterogeneous population. Non-cycloplegic subjective refraction was carried out monocularly using the traditional endpoint of maximum plus [i.e., the best visual acuity (VA) with the maximum plus], followed by cross-cylinder to locate the axis within 5° and its power within 0.25*D*. All exams were performed by the same clinician.

Only patients without present eye disease, injury or surgery at the time of the collected examination where included. This was assessed by general and ocular health examination using non-midriatic direct ophthalmoscope and biomicroscopy. Most of the non-operated patients in the oldest group presented some degree of crystalline lens opacification but they were not excluded as they are a representative part of Portuguese population who usually attend optometric clinics. Patients gave their consent to use data to for anonymous statistical processing. Study protocol was reviewed and approved by the ethics committee of the School of Sciences (University of Minho).

Table 1
Sample distribution within each age group and for the whole population by gender (males vs females).

Age Groups (years)	Males	Females	Total
Children (4 to 8)	33	38	71
Adolescents (9 to 19)	203	385	588
Young Adults (20 to 35)	580	679	1259
Middle-aged Adults (36 to 45)	271	347	618
Adult (46 to 65)	651	652	1303
Elderly (66 to 89)	199	250	449
Total	**1937 (45.2%)**	**2351 (54.8%)**	**4288**

Patients were assigned to one of six different age groups which included children (4 to 8 years); pre-adolescent and adolescent (9 to 19 years); young adults (20 to 35 years); middle-aged-adults (36 to 45 years); adults (46 to 65 years) and elderly (66 to 89 years). This distribution was preferred because it was previously used by Spanish researchers in a similar study (16), making direct comparisons easier, which is of major interest due to the geographical proximity of both populations.

Refractive group assignment was based on spherical equivalent refraction (*SE*=sphere +1/2 cylinder) including myopia ($SE \leq -0.50D$), emmetropia ($-0.50 < SE < +0.50D$) and hyperopia ($SE \geq 0.50D$). For some analyses myopia was divided in three subgroups: "low myopia" ($-0.50D \geq SE \geq -2.00D$); "moderate myopia" ($-2.00D > SE \geq -5.00D$) and "high myopia" ($SE < -5.00D$). Hyperopia was divided in two subgroups: "high hyperopia" ($SE > +3.25D$); "hyperopia" ($+0.50D \leq SE \leq +3.25D$). Regarding astigmatic component, "with-the-rule astigmatism" was defined as an orientation of negative cylinder between 180±30º; "against-the-rule astigmatism" as an orientation of 90±30º; and "oblique astigmatism" as an orientation within the remaining directions not included in the other two groups.

Table 2
Prevalence of refractive conditions (%) expressed by the spherical equivalent refractive error as a function of gender and age group.

Gender	Age Group (years)	Refractive Group							
		Myopia				Emmetropia	Hyperopia		
		High	Moderate	Low	Total		Low	High	Total
Male	4 to 8	3.0	9.1	24.2	36.3	48.5	12.2	3.0	15.2
	9 to 19	3.4	6.9	23.2	33.5	47.3	18.2	1.0	19.2
	20 to 35	2.4	10.2	24.0	36.6	42.2	19.1	2.1	21.2
	36 to 45	5.2	7.4	22.5	35.1	46.5	17.3	1.1	18.4
	46 to 65	2.6	7.4	18.1	28.1	38.7	30.7	2.5	33.2
	66 to 89	2.5	4.0	19.6	26.1	42.2	27.7	4.0	31.7
	Total	**3.0**	**7.8**	**21.3**	**32.1**	**42.3**	**23.4**	**2.2**	**25.6**
Female	4 to 8	2.6	2.6	21.1	26.3	44.7	23.7	5.3	29.0
	9 to 19	2.9	7.0	18.4	28.3	48.3	21.6	1.8	23.4
	20 to 35	3.1	6.6	21.4	31.1	48.9	18.9	1.2	20.1
	36 to 45	2.9	7.2	16.1	26.2	52.2	20.5	1.2	21.7
	46 to 65	2.1	6.4	16.0	24.5	43.7	29.3	2.5	31.8
	66 to 89	2.8	5.6	20.8	29.2	44.0	24.8	2.0	26.8
	Total	**2.7**	**6.6**	**18.5**	**27.8**	**47.3**	**23.1**	**1.8**	**24.9**
Total Population			**29.8**			**45.0**		**25.2**	

Three different criteria were used to define anisometropia in order to compare our results with previous studies. Differences in spherical equivalent refraction between both eyes equal or higher than 1, 2 or 3 diopters were considered to define anisometropia.

Differences between right and left eyes where analyzed using paired-sample T-test, no significant differences were found ($p=0.221$). Hence, only the right eye of each subject was used for subsequent analysis in order to avoid data duplication that could affect the significance of results (18, 19). The level of significance was set at $p<0.05$. ANOVA was performed in order to analyze the potential association of spherical equivalent refraction with age and gender, as well as the differences between presbyopic corrections of males and females. SPSS 13.0 package was used to perform all the statistical analysis.

Table 3
Descriptive statistics (mean, SD) of sphere, cylindrical component and spherical equivalent refraction as a function of age group.

	Age Group (years)	Mean (D)	SD
Sphere	4 to 8	0.07	1.77
	9 to 19	-0.09	2.01
	20 to 35	-0.12	1.80
	36 to 45	-0.17	1.87
	46 to 65	0.20	1.94
	66 to 89	0.25	1.88
Cylinder	4 to 8	-0.68	0.53
	9 to 19	-0.68	0.71
	20 to 35	-0.76	0.71
	36 to 45	-0.68	0.65
	46 to 65	-0.75	0.72
	66 to 89	-0.79	0.77
SE Refraction	4 to 8	-0.27	1.86
	9 to 19	-0.43	2.09
	20 to 35	-0.50	1.87
	36 to 45	-0.51	1.91
	46 to 65	-0.17	2.00
	66 to 89	-0.15	1.90

3. Results

Age and gender distribution are listed in table 1. Gender distribution can be considered as representative of the general population in the north of Portugal, comprising approximately 48% males and 52% females.

Figure 1 presents the frequency distribution of refractive errors defined as spherical equivalent refraction for the whole population. The peak of refraction is in the interval between $-0.49D$ and $+0.49D$ with almost 45% of the population being in this group. Seventy-nine percent of the refractive conditions in our population fall within $\pm 1.50D$ limits. If we consider $\pm 2.00D$, up to 86% of the population presents refractive conditions within these limits.

Mean spherical equivalent refractive error (*SE*) was -0.29 ± 2.01 for the whole sample [range: -26.00 to $+13.00D$]; being $-0.27 \pm 1.96D$ [range: -20.00 to 13.00] for females and $-0.33 \pm 2.08D$ [range: -26.00 to 11.75] for males. No

statistical differences were found between males and females regarding spherical equivalent refraction ($p>0.05$) although a trend is shown towards higher prevalence of ametropia within the male group.

Table 2 reflects the prevalence of myopia ($SE \leq -0.50D$), emmetropia ($-0.50D \leq SE \leq +0.50D$) or hyperopic ($SE \geq +0.50D$), as a function of age, gender and for the whole population. We can conclude that 30% of the general population are myopes, 45% emetropes and the remaining 25% hyperopes. Spherical equivalent refraction varied significantly (one-way, ANOVA) with age ($p<0.001$), with the eye becoming more myopic until the fifties, and the reverse tendency thereafter. If we consider gender as a variable, we only appreciate a shift of the emmetropic condition in females while myopia and hyperopia slightly increase for male subjects as quoted above. Again, the distribution of myopia, emmetropia and hyperopia varied significantly (one-way, ANOVA) as a function of age ($p<0.001$). Young adults from 20 to 35 years old presented the highest prevalence of myopia 33.6%. Conversely, the peak of hyperopic condition was for the population between 46 and 65 years of age (32.5%). Emmetropia seems to display a fairly homogeneous prevalence until the fifth decade of life when an almost 10% decrease is evidenced, given an even higher shift in the hyperopic condition as seen in table 2. Moreover, considering the whole sample, we observed that the more significant changes occur after this age, with both myopia and emmetropia decreasing as hyperopia increases. Differences in mean spherical equivalent refraction among age groups are more influenced by the spherical component which showed a significant trend (one-way, ANOVA) towards hyperopia in the older groups ($p>0.001$). Despite the increase in the value of the cylinder component, no significant differences were detected between age groups. These results are presented in table 3.

Table 4

Frequency (%) of different astigmatic orientation within the different main refractive groups. Note that patients with astigmatism can be included in the emmetropic group if the spherical equivalent falls within the limit (–0.50 < SE < +0.50D).

	Without Astigmatism	Astigmatic Orientation		
		With-the-Rule	Oblique	Against-the-Rule
Myopia	27.5	29.7	15.8	27.0
Emmetropia	27.3	27.6	14.7	30.5
Hyperopia	38.8	13.3	8.2	39.6
Total	**30.2**	**24.6**	**13.4**	**31.8**

Astigmatism between –0.25 and –6.00 was present in 69.8% ($n=2991$) with a value of $-0.74 \pm 0.71D$ (mean ± *SD*). Of those with astigmatism 24,6% displayed with-the-rule astigmatism, 13,4% oblique astigmatism and 31,8% against-the-rule astigmatism. The distribution of astigmatic orientation by refractive group

is shown in table 4. A dramatic change in the prevalence of against-the-rule astigmatism is evidenced in the hyperopic group accounting for 39,6% in this group while its prevalence decrease to 27% for the myopic population. Conversely, the proportion of with-the-rule astigmatism within the myopic group exceeds two-fold that within the hyperopic group.

Anisometropia, defined as a difference in spherical equivalent between both eyes equal or higher than 1*D* was present in 10.1% of the population (432 cases), for a difference between the both eyes equal or higher than 2*D* was present in 3.0% of the population (129 cases) and 1.4% (58 cases) for a difference equal or higher than 3*D*. There were statistically significant differences in the prevalence of this condition as a function of gender ($p<0.001$), being more prevalent in females than males. No differences as a function of age were detected.

Regarding presbyopic condition, there were no significantly differences between the predicted values of near addition as a function of age as described by Hoffstetter (Borish, 1998) and the values of presbyopic addition actually prescribed for males and females. Statistically significant differences were found between average addition values among the three refractive groups (myopic, emmetropic, hyperopic). The most significant differences where found between the emmetropic group compared to myopes and hyperopes ($p<0.001$) than between myopes and hyperopes ($p=0.029$) (one-way, ANOVA). The age for presbyopia onset did not differ between males and females ($p=0.558$) (one-way, ANOVA).

4. Discussion

An increase in the prevalence of myopia has been observed over recent decades, such that approximately 25% of individuals in Caucasian populations today are myopic (11, 20), being even higher for younger groups (21, 22). Moreover, near epidemic levels of myopia have been reported in Asian populations such as Singapore (3), raising over 80% in Chinese people (12).

Results from this study show the first published estimates of prevalence of different degrees of ametropia within a representative sample of the Portuguese population attending eye care clinics. In the present study, we have concluded that 55% of patients present some degree of ametropia, 29.8% of them being myopes and 25.2% being hyperopes.

Our results of prevalence of the three main refractive conditions (myopia, emmetropia and hyperopia) agree with those reported by Midelfart et al in a Norwegian population using a similar criterion for refractive classification ($\pm 0.50D$) (21). These authors studied two age groups separately under non-cycloplegic conditions. They found similar prevalence of emmetropia, a decrease in myopia of 5% and an increase of 4.2% in hyperopia in the older group. Despite a similar behavior of our data, direct comparisons cannot be performed due to the different age range between both studies. In summary, they report approximately the same prevalence of myopia, a higher prevalence of emmetropia and a lower incidence

of hyperopia. This could be due to the fact that previous authors consider +0.50*D* and −0.50*D* as emmetropes while we consider them as hyperopes and myopes, respectively. Recent results from Mallen et al, showed a higher prevalence of myopia with a very low prevalence of hyperopia in a population of Jordanian adults (23). Differences in refractive error determination between that and our study, randomization process and ethnicity among other factors could account for such differences.

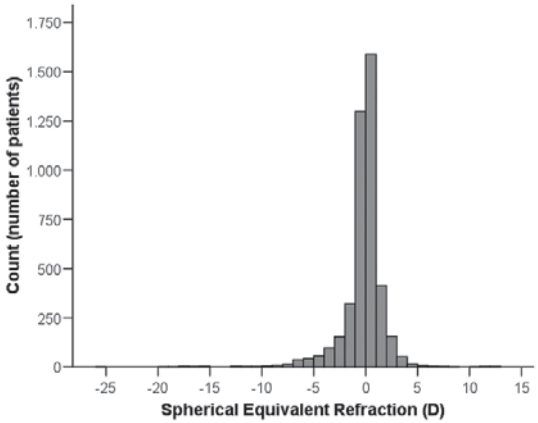

FIG. 1

Refractive error distribution in the total population (n=4288) expressed as spherical equivalent.

Age distribution in our sample population is similar to that reported by Montés-Micó and Ferrer-Blasco, hence we established the same age groupings (16). Despite the same trend towards a decrease in myopia and emetropia and a correspondent increase in hyperopia with age, marked differences are observed between both studies. Our results show a more homogeneous prevalence of refractive conditions across different age groups, with a maximum difference in myopic prevalence of 6% between young adults and adults, a 6.5% decrease in the prevalence of emmetropia between middle-aged adults and adults and a maximum increase in hyperopia of 12.3% between middle-aged adults and adults. Conversely, Montés-Micó and Ferrer Blasco found a maximum decrease in myopic prevalence of 14.9% between young-adults and elderly, a 30% decrease in emmetropia between childhood and elderly and a 16.4% increase in hyperopia from adolescent until elderly.[16] The different criteria to classify refractive conditions could account for such differences. Other potential reason to explain the lower incidence of hyperopia in the younger population group is the fact that present study reflects the prevalence of refractive error in a population attending an optometric clinic. In most cases, younger hyperopes without symptoms do not seek for visual care as frequently as myopes do.

Present results differ from those recently presented by Jorge et al in young-adult university science students (17). One possible explanation is that present results were obtained without cycloplegia which has been demonstrated to give more myopic or less hyperopic values.

Although no significant gender differences were detected, emmetropia was 5% more prevalent in females than males, while males display a slightly higher prevalence of ametropia among all the refractive groups and sub-groups (high myopia, low myopia, emmetropia, low hyperopia and high hyperopia) as a function of age and gender. This result does not agree with the significant trend found by Voo et al which support a higher prevalence of myopia within the female group (24). Shimizu *et al*. using the same cutoff points to classify refractive condition reported a higher prevalence of emmetropia and hyperopia among adult Japanese females, while myopia was more prevalent in males, which is also the case in our population, although with a lower prevalence of myopia as expected in whites compared to Asians.

Our results also demonstrate that the increase in the prevalence of hyperopia is associated with a markedly decrease in the prevalence of myopia after the fifth decade of life, affecting the three subtypes of myopia (low, moderate and high), with the male subjects being responsible for such a trend. Wensor et al found that myopia decreased from 24% to 12% between the groups aged 40 to 49 years and 70 to 79 years, increasing again to 17% after 80 years of age (11). The absence of population younger than 40 in Wensor's sample could account for the lower prevalence of myopia and the higher prevalence of hyperopia, compared to our results. The fact that hyperopes tend to seek for optometric advice later in life than myopes could also account for the higher prevalence of this condition in late adults than in younger adults. This could explain the rapid increase in the prevalence of hyperopia after 45 years of age, when the signs of presbyopia will force latent hyperopia to become manifest. However, we cannot discard the possibility that the prevalence of myopia is increasing in the younger Portuguese generations, probably associated to the increased education levels, which have demonstrated to be associated with the prevalence of myopia.

Different studies carried out in the Scandinavian countries also confirm this behavior. Villarreal et al found myopia worse than –0.50 diopters in 44.9% of 1045 teenagers aged 12 to 13 (22). In Norway, Midelfart et al found that 35% of people between 20 and 25 had myopia worse than –0.50 diopters decreasing to 30.3% for a group between 40 to 45 years old (21).

Regarding astigmatic prescription, as expected, oblique astigmatism was the less prevalent condition among the three refractive groups. Conversely, there is a marked difference between the prevalence of with-the-rule and against-the-rule astigmatism in myopes and hyperopes, with myopes presenting a higher incidence of with-the-rule astigmatism, while against-the-rule astigmatism "seems to be the rule" for hyperopes. Villarreal et al found that myopic patients were more frequently associated with astigmatic prescription (22). The higher prevalence of against-the-rule astigmatism within the hyperopic group could be explained by

the most prevalent hyperopic condition within the older groups that also display a higher prevalence of against-the-rule astigmatism in this and previous studies (25, 26). Results from Raju et al in Indian population found that hyperopia increased until the age of 60 and then decreased (27). They also found an increase of against-the-rule astigmatism with age. Our results corroborate this finding, as patients with against-the-rule astigmatism are significantly older on average.

Regarding anisometropia, we have found this condition in 1.4% of the population when considering between-eye differences of 3 diopters or more as inclusion criteria. Wong et al. found anisometropia defined as a difference in spherical equivalent refraction between right and left eye equal or higher than 1 diopter in 21% of the population (5). Our results revealed a much lower prevalence considering the same criteria with anisometropia equal or higher than 1 diopter affecting 10.1% of the population. These results agree with those reported by Quek et al who found a prevalence of anisometropia of 11.2% with the same criteria (3). Voo et al considering a difference of 2 diopters or more to define anisometropia found this condition in 0.9% of Hispanic people, 1.7% in white Americans and 2.3% in Asian people. If we apply the Voo criterion to our results we found a incidence of 3.0% of anisometropia (24).

Differences found for presbyopic correction among refractive groups must be discussed. The fact that hyperopes show significantly higher values of addition than myopes and emetropes could be due to the highest prevalence of hyperopia within the older groups which obviously present the higher values of addition. No differences were found between males and females for the average value of presbyopic prescription and the onset of presbyopia. Pointer concluded that a higher addition will be required by male as first correction (28).

Despite the limitations inherent to the non-randomized nature of the sample, the present study presents the first report on the prevalence of refractive conditions in the Portuguese population. It is also one of the largest population samples recently published in peer reviewed journals. Main outcomes are that the prevalence of myopia reach almost 30% of the Portuguese population attending an eye clinic with a larger prevalence among the younger groups. Conversely, hyperopia is more prevalent among older patients. No statistical significant differences between males and females were found regarding their refractive condition.

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