Saudi Journal of Ophthalmology (2019) 33, 148–152

Original Article

The distribution of near point of convergence in an Iranian rural population: A population-based cross-sectional study

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Abstract

Objective: To determine the distribution of near point of convergence (NPC) according to age, sex, and refractive error in a rural population above 1 year of age in 2015.
Methods: In this population-based cross-sectional study, multistage cluster sampling was applied to randomly select two underserved areas from the north and southwest of Iran and all individuals above 1 year living in these areas were invited to participate in the study. All participants underwent ocular examinations including visual acuity measurement, refraction, binocular vision testing including cover test and measurement of NPC, and slit lamp biomicroscopy.
Results: Of 3851 who were invited, 3314 participated in the study (response rate: 86.5%). The NPC was 8.42 ± 2.94 cm in the whole population, 8.59 ± 3.07 cm in men, and 8.30 ± 2.84 cm in women. Subjects above 70 years of age had the most remote NPC (mean: 10.44 ± 3.07 cm). The mean NPC was 7.79 ± 2.93, 8.83 ± 2.72, and 9.63 ± 2.70 cm in emmetropic, myopic, and hyperopic participants, respectively. According to the results of a multiple linear regression model, NPC had a positive correlation with age (b: 0.058, $p < 0.001$), male sex (b: 0.336, p: 0.005), and hyperopia (b: 0.044, p: 0.011). Among the evaluated variables, age had the greatest effect on NPC (Standardized coefficient: 0.402).
Conclusion: The distribution of NPC in the Iranian population is different from other populations. Since NPC is influenced by age more than any other variable and presented normal values according to age in this study, the results can be used to interpret clinical measurements for diagnosis and treatment purposes.

Keywords: Near point convergence, Convergence insufficiency, Population-based study

https://doi.org/10.1016/j.sjopt.2019.02.009

Introduction

Different indexes are used to evaluate binocular vision in order to assess the ability of the eyes to adapt to changes of the visual environment, including the near point of convergence (NPC).[1] The NPC is defined as the nearest distance at which the patient does not have double vision. To measure the NPC, the examiner moves a target towards the patient

Received 2 July 2018; received in revised form 22 January 2019; accepted 20 February 2019; available online 4 May 2019.

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Peer review under responsibility of Saudi Ophthalmological Society, King Saud University

Production and hosting by Elsevier

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and the last point at which the patient states double vision or the examiner notices ocular deviation from the target is considered as NPC.[1]

The NPC is important for a number of reasons. First, convergence insufficiency[2] is the commonest binocular dysfunction with a prevalence of 1–33%,[1,3] which is mainly diagnosed through NPC measurement. On the other hand, there is a close relationship between NPC and some ocular disorders like myopia[4] and accommodative insufficiency[3] that affect professional and educational achievements, especially in children.[5]

Despite the significance of NPC in detecting binocular vision problems, few studies have evaluated its distribution and normal values in different populations. Maples,[1] Chen,[6] and Hayes[7] studied children and Momeni-Moghaddam[8] studied university students to determine the distribution of NPC. However, due to narrow age range of the samples in these studies and different values of NPC in different populations, their results may not be generalized to adults or other populations. On the other hand, considering the high prevalence of presbyopia in the elderly population and also decreased accommodative range in presbyopic people that is associated with an increase in NPC,[9] the study population should include the elderly; however, few studies have evaluated the relationship between NPC and presbyopia.[10] Our extensive search only revealed two studies in adults[2,8] but one of them[2] is not reliable because it is not designed for normal values. Ostadimoghaddam et al.[8] conducted a study in individuals aged 10–86 years and provided a comprehensive report of the normal values of NPC. In this study, the man NPC was 6.95 in individuals 10–19 years and 13.06 in subjects above 70 years. The results showed a direct relationship between NPC and old age and male sex, while NPC had no relationship with refractive error. However, other studies may add to our existing knowledge regarding NPC changes. Considering the above, the distribution of NPC may not be similar in different populations and its distribution should be studied locally. The aim of the present study was to evaluate the distribution of NPC in a rural population.

Materials and methods

This cross-sectional population-based study was conducted in rural areas of Iran in 2015. The methodological details of this study have been already published in other articles[11–14] however, they are briefly presented in the following. Considering a prevalence of 6.4% for visual impairment (as the main objective of this research project), type one error of 0.05, precision of 1%, design effect of 1.5, and attrition of 10%, 3850 subjects were randomly selected using multi-stage cluster sampling.

A list of all underserved areas of Iran was prepared and two districts were selected randomly in the north and southwest of the country. These districts were Shahyon (a district of Dezful County, Khuzestan Province) and Kojur (a district of Nowshahr County, Mazandaran Province) (Fig. 1). Then, a number of villages were randomly selected in each district from a list of all villages in these districts (15 villages in Shahyon and 5 villages in Kojur). Arrangements were made with authorities in these villages and districts and all individuals above 1 year residing in these villages were invited to participate in the study. Informed consent was obtained from the participants or their legal guardians if the person was under 18 years. In each village, the examinations were done in a room with standard illumination (1300 lux) in one day. Demographic information including age, sex, education and etc. were collected via interview before optometric examinations were done. All examinations were done by two optometrists. A pilot study of 35 subjects showed a high inter-examiner agreement (intraclass correlation coefficients = 0.923 for uncorrected visual acuity and 0.897 for spherical equivalent of refraction). The examinations included the measurement of visual acuity and refraction, binocular vision examinations, and assessment of ocular health.

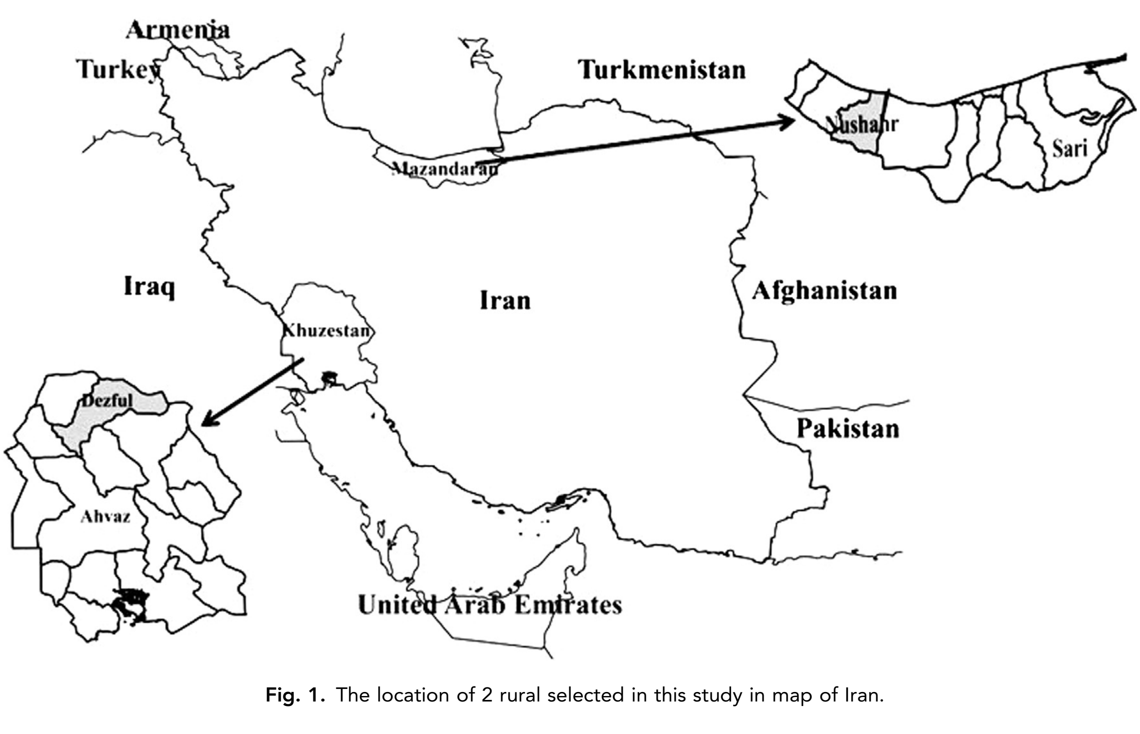

Fig. 1. The location of 2 rural selected in this study in map of Iran.

For each participant uncorrected visual acuity (UCVA) was first measured using a Snellen E chart at 6 meters. Illiterate subjects were instructed before testing. A Lea Symbols acuity chart was used in children ≤ 5 years. For objective refraction, autorefraction was done using the Nidek Ref/Keratometer ARK-510A, and its results were refined with retinoscopy (Heine Beta 200 retinoscope, HEINE Optotechnik, Germany). Then, distance and near subjective refraction were measured and best corrected distance and near visual acuity (BCVA) were recorded. In the next stage, binocular vision tests including a near and far cover test and NPC measurement were done using the best optical correction (near correction for presbyopic subjects). Distance and near unilateral and alternate cover test was tested using a prims bar at 6 m and 40 cm in order to evaluate the status of ocular alignment. The target for the cover test was one row above the corrected visual acuity threshold (in the eye with weaker visual acuity) on the distance and near Snellen chart. After the cover test, the NPC was measured using a 6/12 single target on a Gulden fixation stick held at midline. For this purpose, the target was slowly moved towards the subject's eye at a rate of 1 cm/s and the patient was asked to report when persistent double vision occurred. When the patient reported double vision (Subjective endpoint) or the examiner noticed loss of binocularity (objective endpoint), the distance between the target and the spectacle plane or lateral canthus (if the subject did not wear glasses during the examination) was measured.[1,15] To increase the test accuracy, the NPC was measured five times and the average of the measurements was used for analysis.

Next, slit lamp biomicroscopy was done by an ophthalmologist for all subjects. Finally, all participants under 15 years of age underwent cycloplegic auto-refraction[16] 35 min after instilling cyclopentolate 1% drops twice at a 5 min interval.

The exclusion criteria were strabismus, amblyopia, visual acuity worse than 20/40 in either eye, history of ocular surgery or trauma, ocular or systemic pathologies affecting accommodation and binocular vision, and use of ocular or systemic drugs affecting accommodation and binocular vision.

Statistical analysis

After collecting demographic and clinical data, a trained operator entered them into the SPSS software version 18 for analysis. Quantitative data are presented as mean, standard deviation, and 95% confidence interval. A simple and multiple linear regression model was applied to evaluate the correlation of age, sex, and refractive error with NPC. The effect of cluster sampling was considered for standard error calculation. *P* values less than 0.05 were considered significant.

Results

Of 3851 individuals who were invited, 3314 participated in the study (response rate = 86.5%). Female subjects comprised 56.3% (*n* = 1843) of the participants. The mean age of the study sample was 37.7 ± 21.4 years (range = 2–93 years). The largest age group was 6–20 years (23.3%). As for the education level, 33.4% of the subjects were illiterate.

Table 1 presents the mean NPC according to demographic variables. The mean NPC was 8.42 ± 2.94 cm in the study population, 8.59 ± 3.07 cm in men, and 8.30 ± 2.84 cm in women. Emmetropic subjects had the shortest NPC. The NPC increased with age and was the most remote in subjects above 70 years of age.

Table 2 shows the results of the simple and multiple linear regression model for NPC. According to simple linear regression analysis, age (b: 0.62; $p < 0.001$), male sex (b: 0.285; *p*: 0.030), and myopia (b: 1.035; $p < 0.001$) had a direct relationship with NPC. According to the multiple linear regression, NPC had a significant positive relationship with age (b: 0.058; $p < 0.001$) and male sex (b: 0.336; *p*: 0.005). Although myopia had no correlation with NPC, the mean NPC was increased in hyperopic individuals as compared to emmetropic subjects (b: 0.044; *p*: 0.011). Among the study variables, age had the greatest effect on the NPC (Standardized coefficient: 0.402).

Discussion

This study was conducted in a large population of different age groups to provide a comprehensive view of NPC changes according to age for the first time; therefore, its results can be used in diagnostic judgments and treatment

Table 1. Mean of near point of convergence in term of sex, age, city and refractive error in study population.

Variables		Near point of convergence (cm)			
		Mean ± SD	min	max	Percentile 85%
Sex	Female	8.30 ± 2.84	2.00	20.00	10.00
	Male	8.59 ± 3.07	2.00	22.00	11.00
Age group	<=5	5.63 ± 1.90	3.00	14.00	8.00
	6–20	6.61 ± 2.60	2.00	22.00	8.00
	21–30	8.32 ± 2.45	2.00	20.00	10.00
	31–40	8.72 ± 2.50	2.00	20.00	10.00
	41–50	9.45 ± 2.81	4.00	20.00	12.00
	51–60	9.51 ± 2.66	3.00	20.00	12.00
	61–70	9.53 ± 2.76	5.00	20.00	12.00
	>70	10.44 ± 3.07	5.00	20.00	14.00
City	East	9.11 ± 3.00	2.00	22.00	12.00
	North	7.51 ± 2.59	2.00	20.00	10.00
Refractive errors	Emmetropia	7.79 ± 2.93	5.00	20.00	13.85
	Myopia	8.83 ± 2.72	2.00	20.00	10.00
	Hyperopia	9.63 ± 2.70	2.00	22.00	12.00
Total		8.42 ± 2.94	2.00	22.00	11.00

Table 2. simple and multiple linear regression between near point of convergence with age, sex and refractive error in study population.

Variables	Near point of convergence (cm)				
	Simple linear regression		Multiple linear regression		
	Unstandardized coefficient	*P* value	Unstandardized coefficient	*P* value	Standardized coefficient
Age	0.62 (0.056–0.067)	<0.001	0.058 (0.051–0.064)	<0.001	0.402
Sex (female = 0)	0.285 (0.028–0.542)	0.030	0.336 (0.103–0.569)	0.005	0.056
Myopia[a]	1.035 (0.732–1.339)	<0.001	0.147 (−0.156 to 0.451)	0.341	0.020
Hyperopia[a]	1.840 (1.538–2.142)	<0.001	0.044 (0.102–0.783)	0.011	0.061

[a] Emmetropia is baseline group.

decisions. Caution should be exercised when comparing NPC in different studies because differences in NPC in different populations, in addition to genetic and environmental factors, may be influenced by the measurement method as subjective measurements are associated with overestimation.[17]

Despite the importance of age in determining NPC changes, no study has evaluated the distribution of NPC in different age groups, a shortcoming which we tried to overcome in this study. According to von Noorden et al.[18] a near point of conversion less than 5 cm is excessively close and an NPC more than 10 cm is defective; however, is not possible to make a definite comment in this regard because this parameter depends on different variables. The mean NPC was 8.42 ± 2.94 cm in the present study, which was very close to the result of similar domestic studies.[8] Hayes et al.[7] reported an NPC of 3.3, 4.1, and 4.3 cm in kindergarten, third grade, and sixth grade children using the push-up method. Borsting et al.[19] and Rouse et al.[20] reported a mean NPC of 2.7 and 3 cm in individuals aged 8–13 years and Chen et al.[6] reported a mean NPC of 1.9 cm in children and adolescents aged 1–18 years. The range of NPC regardless of age is 5–15 cm in the literature.[10,21] Comparison of the above results shows that NPC, in addition to age,[22] is affected by race, population, and environment. Studies have shown that people living in tropical regions are more susceptible to presbyopia due to intense sunlight and less humidity,[23] and differences in the prevalence of presbyopia may be a reason for NPC differences. Although Noorden et al.[21] reported that NPC does not change with age, the results of this study as well as some other studies have shown the opposite.[7,8] According to the results of multiple linear regression, age had the greatest effect on NPC, indicating a strong relationship between age and NPC (Standardized coefficient: 0.402). Consistent with other studies[7,8] Our study also showed that the mean NPC increased significantly with aging that has been attributed to decreased accommodative convergence[6] and overspread of the inter-pupillary distance.[7] Some studies have shown a linear increasing trend for NPC.[8] Similar to the above study, we also noticed an almost linear increase in the NPC with ageing. However, the range of NPC changes was very wide in subjects above 70 years (SD: 0.07) which seems to be due to the small sample size of this age group.

Comparison of NPC break points in different age groups showed a higher break point in our study as compared to foreign studies. For example, a break point of 3–8 cm was reported in the age group 6–18 years in the FAAO study[23] while the mean NPC in this age group was 6.61 cm in our study, which was rather closer to the upper limit. Moreover, in another study conducted in Iranian university students, the NPC was similar to the age group evaluated in our study.[24] It should be borne in mind that the reason for the difference, in addition to genetic and environmental factors, may be differences in the measurement method.[15]

There are controversies about inter-gender differences in the NPC. Held et al.[25] reported a difference in NPC between men and women because of the earlier onset of shift to fusion preference and full convergence in women. In line with other studies,[8] our study also showed a significant difference in the NPC between men and women while Chen et al.[6] found no such difference. It should be noted that the difference in NPC between men and women was less than 0.3 cm in our study and since this difference was equal to an effect size of 0.09, in line with the Cohen's report,[26] it is clinically non-significant and can be ignored. Rouse et al.[20] also reported that any NPC difference less than 3 cm is clinically non-significant.

Refractive errors also affect the NPC. Based on multiple linear regression, our study showed a higher mean NPC in hyperopic versus emmetropic subjects and the difference was still observed after controlling the effect of age and sex. In line with our study, Ostadimoghaddam et al.[8] also reported a higher mean NPC in hyperopic subjects as compared to individuals with myopia but the difference was not significant after controlling the effect of age and sex. It seems that hyperopic individuals have a lower amplitude of accommodation despite higher tonicity for accommodation[27] and therefore have a reduced accommodative convergence, which is associated with an increased NPC. However, our extensive search did not reveal any mechanism for the relationship between NPC and refractive errors, indicating the need for more studies in this regard.

This was the first study of the normal range of NPC in underserved areas in Iran. The most important strength of our study may be the wide age range of the participants as we recruited subjects aged 1–90 years, which enhanced our understanding of NPC changes with ageing. Other advantages of our study were its large sample size and using trained optometrists for NPC measurement.

Conclusion

NPC in our study was similar to other domestic studies but different from foreign studies. The NPC break point was higher in our study when compared to foreign studies. NPC is affected by age more than any other variable. Since our NPC measurements were very accurate, the results may be used for interpretation of clinical measurements for diagnostic and treatment purposes.

Clinical implications of study

Accurate measurement of NPC in the clinical setting is very important for assessment of neuromuscular anomalies.

With regards to the importance of age in NPC, clinicians should consider its role before presenting any treatment protocol.

Financial support

This project was supported by Shahid Beheshti University of Medical Sciences.

Conflict of interest

The authors declared that there is no conflict of interest.

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