Original Article

Normative values for near point of convergence among university students in Oman

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ABSTRACT

Background: Near point of convergence (NPC) is a key clinical measure used in the assessment of binocular vision function and the diagnosis of convergence insufficiency. Normative NPC values vary across populations and are influenced by demographic and methodological factors. However, population-specific normative data for NPC are lacking in Oman. This study aimed to establish normative NPC break and recovery values among emmetropic university students in Oman and to examine variations by sex and age.

Methods: This prospective cross-sectional study was conducted among students at the University of Buraimi, Oman. Emmetropic participants aged 17–25 with best-corrected distance visual acuity 20/20 or better, near visual acuity N6, normal binocular vision, and a Convergence Insufficiency Symptom Survey (CISS) score ≤ 21 were included. NPC break and recovery points were measured subjectively using a standardized Royal Air Force (RAF) ruler with an accommodative target. Three consecutive measurements were obtained for each parameter, and mean values were recorded. Descriptive statistics were calculated, and comparisons by sex and age group were performed using independent-samples t-tests and one-way analysis of variance, respectively.

Results: A total of 350 participants (74.9% female) met the inclusion criteria, with a mean (standard deviation [SD]) age of 20.16 (1.78) years. The overall mean (SD) NPC break point was 10.0 (2.6) cm (95% confidence interval [CI]: 9.7–10.3 cm) and the mean (SD) recovery point was 12.0 (2.0) cm (95% CI: 11.8–12.2 cm). Mean (SD) CISS score was 11.3 (6.3) (95% CI: 10.6–11.9), indicating a largely asymptomatic cohort. Females showed significantly more remote NPC break and recovery points than males (break: 10.2 vs 9.4 cm, $P < 0.05$; recovery: 12.2 vs 11.5 cm, $P < 0.05$). No statistically significant differences in NPC break or recovery values were observed across age groups (17–19, 20–22, and 23–25 years; $P > 0.05$).

Conclusions: This study provides the first population-specific normative NPC break and recovery values for young adults in Oman using a standardized RAF ruler method. NPC measurements were influenced by sex but not by age within the examined range, reflecting the relative stability of convergence function in young adulthood. These findings offer clinically relevant reference values for optometric practice in Oman, underscoring the importance of establishing population- and context-specific normative data to enhance the assessment and management of binocular vision disorders.

KEYWORDS

normative values, near point of convergence, university students, RAF ruler, near point convergence, binocular vision, ocular convergence, optometry, ophthalmology

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INTRODUCTION

Normative data comprise empirical observations that define what is considered typical or expected within a specified reference population [1]. Such data are inherently population-specific, as normative values may vary according to demographic, environmental, and methodological factors. Near point of convergence (NPC) is defined as the closest point in space along the median plane, directly in front of the patient's face, at which the visual axes can be voluntarily converged and maintained [2–4]. Assessment of NPC is a fundamental component of a comprehensive eye examination and represents a primary clinical measure for the diagnosis and management of convergence insufficiency [5]. Consequently, evaluation of NPC is particularly important in individuals with substantial near visual demands, such as students and professionals engaged in prolonged near work [6].

Previous investigations have evidenced that NPC tends to recede with age [7]. Some studies have also reported sex-related differences, suggesting higher NPC values in males compared with females [8], yet findings remain inconsistent and the association between NPC and sex has not been conclusively established. In addition, NPC measurements are influenced by both type of accommodative target and measurement technique used. Variability associated with different targets, as well as the effects of the Royal Air Force (RAF) ruler, observer experience, and subject anticipation, have been reported [9].

Accurate interpretation of NPC findings requires comparison with appropriate normative data, which may differ substantially across populations. Existing studies reporting normative NPC values have been conducted over different time periods and geographic regions, involving diverse demographic groups [10–13]. However, to date no studies have established normative NPC values for the Omani population. Given documented global variations in natural environments, cultural practices, and lifestyle factors that may influence the visual system [14–16], normative data derived from other populations may not be directly applicable to individuals in Oman.

Hence the present study aims to establish normative NPC values among university students in Oman, using students from multiple colleges at the University of Buraimi as the target population.

METHODS

This prospective cross-sectional study was conducted among university students at the University of Buraimi (UOB), Al Buraimi, Sultanate of Oman. Ethical approval was obtained from the Research and Ethics Committee of the University of Buraimi (Approval No. AY24-25COHS-099). All study procedures were performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment, and strict measures were implemented to ensure confidentiality and data protection. Participation was voluntary, and no physical or psychological harm was reported in the course of the study.

Eligible participants were emmetropic university students with best-corrected distance visual acuity 20/20 or better and near visual acuity N6, normal binocular vision, and a Convergence Insufficiency Symptom Survey (CISS) score ≤ 21 [17]. Participants with a history of ocular disease, amblyopia, strabismus, ocular trauma, or strabismus surgery were excluded. Additional exclusion criteria were presence of any ocular pathology, systemic disease known to affect visual function, ametropia, or a history of previous treatment for binocular vision abnormalities.

According to recent institutional statistics, the University of Buraimi has a total student population of 3478, distributed across four colleges (Business, Engineering, Health Sciences, and Law) and 40 academic programs. Students aged 17–25 were randomly selected for participation in this study. The required sample size was calculated using the standard formula for estimating a population proportion: sample size = $[Z^2p\ (1 - p)]/\ C^2$, where Z represents the standard normal deviate corresponding to a 95% confidence level (1.96), p is the anticipated population proportion (assumed to be 0.50 in the absence of prior data), and C is the maximum allowable margin of error (0.05) [18]. Based on these parameters, the minimum required sample size was estimated to be 294 participants. To account for a potential nonparticipation rate of approximately 10%, the final target sample size was increased to 350 participants. The number of participants ultimately recruited met and exceeded the calculated minimum sample size, thereby enhancing the precision and reliability of the study estimates.

All participants underwent a comprehensive baseline ophthalmic examination conducted by trained optometrists. Best-corrected distance visual acuity was assessed using a crowded Keeler logarithm of the minimum angle of resolution chart (Keeler Ltd., Windsor, UK) at a testing distance of 4 m under standardized photopic illumination. Near visual acuity was evaluated binocularly using a standard near vision chart at a working distance of 40 cm with appropriate near correction where required. Anterior segment evaluation was performed using slit-lamp biomicroscopy (Haag-Streit BX 900; Koeniz, Switzerland). Posterior segment assessment was carried out using the same slit lamp in conjunction with a condensing lens.

NPC break and recovery points were measured subjectively using a RAF ruler [9, 19]. NPC assessment was performed using a standard accommodative target consisting of a sharpened pencil tip, positioned along the RAF ruler and moved slowly toward the participant along the midline. Participants were instructed to maintain single, clear fixation on the target and to report the onset of diplopia. The NPC break point was defined as the distance at which diplopia was first perceived, and the recovery point was recorded as the distance at which single vision was regained as the target was moved away. Three consecutive measurements of both break and recovery were obtained for each participant, calculating the mean of the three readings for statistical analysis. All measurements were conducted by the same examiner using the same RAF ruler to ensure

methodological consistency and minimize inter-examiner variability. Testing was done under full room illumination for all participants.

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 28.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test. Categorical variables were summarized as frequencies and percentages, while continuous variables were expressed as means and standard deviations (SDs) with corresponding 95% confidence intervals (CIs). Descriptive statistics were used to establish normative values for NPC break and recovery points and CISS scores. Comparisons of mean NPC values between sex groups were conducted using independent-samples *t*-tests. Differences in NPC break and recovery points across age groups were analyzed using one-way analysis of variance (ANOVA). All statistical tests were two-tailed, and a *P*-value < 0.05 was considered statistically significant.

RESULTS

A total of 350 university students from four colleges at the University of Buraimi met the study eligibility criteria and completed the CISS. Mean (SD) age of the participants was 20.2 (1.8) years. Females constituted 74.9% (n = 262) of the sample, males accounted for 25.1% (n = 88). The distribution of participants by age group and sex is presented in Table 1.

For the overall study population, the mean (SD) NPC break point was 10.0 (2.6) cm and the mean (SD) recovery point was 12.0 (2.0) cm. Mean (SD) CISS score was 11.3 (6.3). Corresponding 95% CIs for these parameters are summarized in Table 2.

Comparisons by sex revealed statistically significant differences in NPC measurements. Females displayed significantly greater mean (SD) NPC break and recovery points compared with males (break point: 10.2 [2.6] cm vs 9.4 [2.5] cm, $P < 0.05$; recovery point: 12.2 [1.8] cm vs 11.5 [2.3] cm, $P < 0.05$) (Table 3).

When analyzed across age groups, no statistically significant differences were observed in NPC break or recovery points (both $P > 0.05$). The mean (SD) NPC break points for participants aged 17–19, 20–22, and 23–25 years were 9.9 (2.5) cm, 10.1 (2.5) cm, and 9.6 (3.1) cm, respectively, with the highest mean value observed in the 20–22 age group. Similarly, the mean (SD) NPC recovery points for the corresponding age groups were 12.0 (2.0) cm, 12.2 (1.9) cm, and 11.5 (2.3) cm, with the highest value again noted in the 20–22 age group (Table 3).

Table 1. Demographic data of study participants

Age groups (y)	Female, n (%)	Male, n (%)
17–19	121 (82.3)	26 (17.7)
20–22	127 (75.6)	41 (24.4)
23–25	14 (40.0)	21 (60.0)
Total	262 (74.9)	88 (25.1)

Abbreviations: y, years; n, number of participants. Note: P-value < 0.05 is shown in bold.

Table 2. Value of NPC and CISS score in study participants (N =350)

Variable	Mean ± SD	95% CI
Break point (cm)	10.0 ± 2.6	9.7 to 10.3
Recovery point (cm)	12.0 ± 2.0	11.8 to 12.2
CISS Score	11.3 ± 6.3	10.6 to 11.9

Abbreviations: NPC, near point of convergence; CISS, convergence insufficiency symptom survey questionnaire, n, number of participants; SD, standard deviation; CI, confidence interval; cm, centimeter.

Table 3. NPC differences between groups

Category			Mean± SD	95% CI	*P*-value
Sex group	**Break point (cm)**	Female	10.2 ± 2.6	9.9 to 10.5	**0.008**
		Male	9.4 ± 2.5	8.8 to 9.9	
	Recovery point (cm)	Female	12.2 ± 1.8	11.0 to 12.4	**0.003**
		Male	11.5 ± 2.3	11.0 to 12.0	
Age group (y)	**Break point (cm)**	17–19	9.9 ± 2.5	9.5 to10.3	0.420
		20–22	10.1 ± 2.5	9.8 to 10.5	
		23–25	9.6 ± 3.1	8.5 to 10.6	
	Recovery point (cm)	17–19	12.0 ± 2.0	11.7 to 12.3	0.150
		20–22	12.2 ± 1.9	11.9 to 12.5	
		23–25	11.5 ± 2.3	10.7 to 12.3	

Abbreviations: NPC, near point of convergence; SD, standard deviation; CI, confidence interval; cm, centimeter. Note: *P*-values < 0.05 are shown in bold.

DISSCUSSION

The present study established normative values for NPC break and recovery among emmetropic university students in Oman using a standardized RAF ruler method. In this cohort, the mean NPC break and recovery points were 10.0 cm and 12.0 cm, respectively, with a mean CISS score well below the symptomatic threshold; this confirmed normal binocular visual function in the study population. Significant sex-related differences were observed, with females demonstrating slightly greater NPC break and recovery distances than males. In contrast, NPC values did not differ significantly across the examined age groups, indicating relative stability of convergence function within the young adult age range of 17–25 years. Collectively, these findings provide population-specific normative NPC data for Omani university students and support the influence of sex, but not age, on NPC measurements within this demographic.

Assessment of convergence is a fundamental component of a comprehensive eye examination and is essential to the diagnosis of a range of nonstrabismic binocular vision anomalies [20, 21]. Although numerous studies have reported normative values for binocular function across different populations [10–13], there is a notable lack of region-specific data addressing NPC measurements in Oman and the surrounding region [1, 2]. The present study addresses this gap by establishing normative NPC values among university students in Oman and by examining variations according to sex and age. In our overall study population, the mean (SD) NPC break point was 10.0 (2.6) cm (95% CI: 9.7–10.3 cm) and the mean (SD) recovery point 12.0 (2.0) cm (95% CI: 11.8–12.2 cm). Mean (SD) CISS score was 11.3 (6.3), with a corresponding 95% CI of 10.6–11.9, indicating a largely asymptomatic cohort. These NPC values are lower than those reported in studies involving similar age groups in the Indian population and higher than those reported in Saudi and Iranian populations [3, 8, 9]]; such variations may—at least in part—be attributable to differences in study design, population characteristics, and measurement techniques employed across studies [3, 8, 9].

In the present study, sex was found to have a statistically significant influence on NPC, with females exhibiting slightly more remote break and recovery points than males. This finding contrasts with the results reported by Hashemi et al. for a large Iranian rural population, in which males demonstrated significantly more remote NPC values than females, despite females comprising 56.3% of the study sample [8]. In that study, male sex remained an independent predictor of increased NPC after adjusting for age and refractive error, although age exerted the strongest overall effect. Similarly, Ostadimoghaddam et al. [7] reported a significant association between male sex and more remote NPC values in a population-based cohort in which 67.8% of participants were female, spanning a broad age range from childhood to older adulthood (10–86 years) [7]. In contrast, findings from the Tehran Geriatric Eye Study, in which 59.6% of participants were female, indicated no statistically significant differences in NPC between males and females among elderly individuals aged 60 years and older [22], suggesting that sex-related effects on convergence may diminish or become less detectable in later life.

Several factors may account for the discrepancies observed between the present study and these previous reports [7, 8, 22]—notably, the cited population-based studies included wide age ranges and heterogeneous refractive profiles [7, 8, 22], whereas the current study was restricted to a narrow young adult age group and exclusively emmetropic participants with normal binocular vision and a low symptom burden. In addition, differences in measurement techniques—such as the use of fixation sticks or dissociative targets in these prior studies [7, 8, 22] compared with the standardized accommodative RAF ruler method employed in the present study—may influence NPC outcomes and their sensitivity to sex-related differences. The unequal sex distribution in the current sample, with its predominance of female participants (74.9%), may have likewise contributed to the direction and magnitude of the observed differences. Overall, these findings indicate that the association between sex and NPC is not uniform across populations [7, 8, 22] and appears to be modulated by age range, refractive status, and methodological approach, underscoring the importance of population- and context-specific normative data.

In the present study, no statistically significant differences were observed in NPC break or recovery values across the examined age groups (17–25 years). This finding is most plausibly explained by the relative age homogeneity of the study population, which represents a narrow young adult range characterized by stable accommodative and vergence function. In contrast, Abraham et al. [13] reported a progressive recession of NPC with increasing age in an Indian non-clinical population spanning a much wider age range (10–35 years). The age-related changes observed in their study were attributed to increases in near horizontal phoria with advancing age, a factor less likely to exert a measurable effect within the limited age span of the present cohort. Methodological differences may further account for the discrepancy, as they employed a red-green dissociative target for NPC measurement, whereas the current study used a standardized accommodative RAF ruler method that may yield different sensitivity to subtle age-related changes [13]. Similarly, Gavin et al. [23] demonstrated a gradual decline in convergence ability with advancing age in adults older than 50, with NPC values increasing notably in later decades of life. Their findings reinforce the notion that age-related changes in NPC become more pronounced beyond early adulthood, likely reflecting cumulative alterations in vergence control, visual attention, and neuromuscular efficiency [23]. In contrast, the absence of age-related differences in the present study aligns with the physiological expectation that convergence function remains relatively stable during young adulthood. These comparisons suggest that age-related effects on NPC are highly dependent on the breadth of the age range studied and the measurement techniques employed [9, 13, 23], underscoring the importance of population-specific normative data. The current findings therefore provide clinically relevant normative NPC values for young adult Omani university students, a demographic not previously represented in the literature.

Variations in the target population and environmental visual demands may significantly influence convergence performance [24, 25]. For instance, populations with high near-work demands or early exposure to digital devices may exhibit distinct oculomotor adaptations [26, 27]. The methodology employed in studies plays a crucial role; diverse testing targets such as the Snellen chart, accommodative targets, or subjective measurements can substantially affect NPC outcomes [7–9, 13, 22, 23]. The age range and demographic characteristics of the samples varied considerably across studies, complicating direct comparisons [7–9, 13, 22, 23, 28]. Despite these differences, the literature consistently indicates that younger age groups tend to have closer NPC values, whereas older groups exhibit more remote break and recovery distances [13, 29]. Although this study did not identify a significant effect of age within the narrow 17–25 age range, our findings align with the broader trend that convergence ability gradually decreases with age.

This study has several strengths, including the use of a standardized and clinically relevant RAF ruler method, a well-defined and adequately powered sample, and strict inclusion criteria that ensured a homogeneous cohort of emmetropic young adults with normal binocular vision and low symptom burden. In addition, this work represents the first effort to establish population-specific normative NPC values for university students in Oman, addressing an important gap in the regional literature. Nevertheless, several limitations should be considered when interpreting the findings. First, the study sample comprised exclusively young adults aged 17–25 from a single university, which limits the generalizability of results to the broader Omani population—particularly children and older adults, in whom NPC performance may differ. Second, the study employed a single NPC measurement method and did not include additional binocular vision assessments, which may have provided a more comprehensive evaluation of convergence function. Third, although the overall sample size was sufficient, the unequal sex distribution with a predominance of female participants may have influenced the sex-related differences observed. Last, NPC measurements were obtained during a single testing session so potential influencing factors such as fatigue, time of day, and recent near-work activity were not controlled, which could have affected measurement accuracy. Future research should include a wider age range to establish normative NPC values across the lifespan in Oman, ideally using a multicenter design encompassing different geographic regions. Incorporation of multiple measurement techniques and additional binocular vision assessments is recommended to better elucidate factors influencing NPC performance. Longitudinal studies would be valuable for monitoring age-related changes in convergence ability, and future investigations should also document near-work habits and screen time, as these variables may significantly impact NPC outcomes within the population.

CONCLUSIONS

This study establishes population-specific normative values for NPC among emmetropic young adults in Oman using a standardized RAF ruler method. Among university students at the University of Buraimi, the mean (SD) NPC break and recovery points were 10.0 (2.6) cm and 12.0 (2.0) cm, respectively, with low CISS scores confirming a largely asymptomatic cohort. No statistically significant age-related differences in NPC were observed, a finding likely attributable to the narrow and physiologically stable age range of the study population. In contrast, sex was found to significantly influence NPC measurements, with females displaying slightly more remote break and recovery points than males. These findings provide the first normative NPC data for young adults in Oman and highlight the importance of population- and context-specific reference values for accurate clinical interpretation of convergence function. The results support use of these normative values in routine optometric practice and emphasize the need for future multicenter and longitudinal studies encompassing broader age ranges, diverse refractive profiles, and additional binocular vision assessments to further refine diagnostic criteria and improve the clinical management of binocular vision disorders.

ETHICAL DECLARATIONS

Ethical approval: Ethical approval was obtained from the Research and Ethics Committee of the University of Buraimi (Approval No. AY24-25COHS-099). All study procedures were performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment, and strict measures were implemented to ensure confidentiality and data protection. Participation was voluntary, and no physical or psychological harm was reported in the course of the study.

Conflict of interests: None.

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