

Prevalence and risk factors of Keratoconus among school children in Oman: A Population Based Study

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Abstract

Background

To investigate the prevalence and risk factors of keratoconus [KC] among Omani school children.

Methods

The study employed a cross-sectional, population based, descriptive design. A cohort of school students, aged 9 to 18 years from the Al Buraimi Governorate of Sultanate of Oman underwent comprehensive ocular assessments, including auto-kerato-refractometry (ARK), retinoscopy, and corneal topography. A binary logistic regression analysis was performed to identify the independent predictors of KC.

Results

A total of 733 students participated (mean age 13.95 ± 2.19 years) and 67.4% were males. Twelve participants (1.6%) met criteria for keratoconus (KC), and 5.0% were classified as keratoconus suspect (KCS). Regression analysis identified the scissor reflex as the strongest predictor of both KCS (OR = 848.52, 95% CI: 168.03–4284.93; $p < 0.001$) and KC (OR = 120.65, 95% CI: 16.98–857.25; $p < 0.001$). Among KC cases, frequent eye rubbing (OR = 13.60; $p = 0.020$) and parental consanguinity (OR = 21.77; $p = 0.021$) were also significant risk factors.

Conclusion

Keratoconus prevalence in this study aligns with regional reports, confirming a higher burden than in Western populations. Consanguinity as a significant predictor underscores the need for genetic counseling and risk awareness, and the strong predictive value of the scissor reflex supports the use of retinoscopy in screening.

Background

Keratoconus (KC) is an ectatic corneal disorder with multifaceted etiology and pathogenesis [1]. The resulting progressive corneal changes range from irregular myopic astigmatism to corneal scarring and may potentially lead to severe visual impairment [1, 2]. As compared to adult KC, pediatric KC has more severe presentation, rapid progression and higher odds of developing corneal hydrops and corneal opacity. This increases the risk of severe visual disability and the need for early clinical intervention.

The prevalence of pediatric KC varies widely across ethnic populations and geographical regions [3, 4]. The prevalence rate varies from a very low rate in the western populations to significantly higher rates in

regions with greater genetic and environmental susceptibility such as Middle East, South Asia and Africa [4–7]. Recent reports indicate that the prevalence of KC in pediatric / school-aged population ranges from 0.02–0.09% in some Russian and New Zealand cohorts [8–10], to 0.7–1.7% in Brazil [11] and Kenya [12] and up to 2.0–5.5% in the Middle-Eastern region [7, 13–16]. Despite growing recognition of KC as a major pediatric eye health concern, epidemiological data is limited from the parts of the Arabian Peninsula.

Across populations, the most prevalent predisposing factors for KC are vigorous eye rubbing [17, 18], genetic susceptibility (family history/consanguinity) [19–21] and atopic/allergic diseases [17, 18, 20] and a strong contributing evidence of dry climates [19, 22, 23]. Such environmental factors trigger or accelerate KC in genetically susceptible corneas. These predisposing factors like genetic susceptibility, and dry and dusty environmental conditions are actively prevalent in Oman. The current best estimate of KC prevalence (among young adults) in Oman is 3.5%, and it observed that a significant proportion of cases are detected at advanced stages, with variations noted across geographic regions in the country [24, 25]. These patterns highlight the need for targeted screening strategies and early detection. Therefore, the present study aims to determine the prevalence of KC among pediatric population in a governorate in Oman to contribute epidemiological evidence to guide early screening and management.

Methods

Study design

This study employed a cross-sectional, population-based descriptive design conducted in the Sultanate of Oman between January 2025 and January 2026.

Geographical area description

The Sultanate of Oman is located in the southeastern corner of the Arabian Peninsula, bordered by the United Arab Emirates, Yemen, and Saudi Arabia with extensive coastal lines, desert and mountain ranges in the interiors, which influence community settlement patterns and environmental exposures [26]. Culturally, the Sultanate is characterized by a blend of Arab, Islamic and maritime traditions. Social structures are community-oriented, with strong family ties. Oman experiences mostly arid and semi-arid conditions, with high temperatures, low humidity in interior regions, and seasonal dust and sand exposure [27]. Ultraviolet radiation levels are high year-round. This study was conducted in the Al-Buraimi governorate located in the northwestern part of Oman, bordering the United Arab Emirates.

Study setting and sample

The study consists of school children attending 12 government schools from grades 4 to 12 within the three wilayat of Al-Buraimi Governorate. A stratified cluster and random sampling method was adopted

to identify the required number of samples from each school as subgroups. The sample size was calculated to estimate keratoconus prevalence with a 95% confidence level and $\pm 1.75\%$ precision, assuming an expected prevalence of 3.5%. After adjusting for cluster sampling and a 10% nonresponse rate, a minimum sample of approximately 700 participants was required. Consent forms were distributed to parents and those who were agreed upon were only included in the study. In instances where a child was absent from school during the screening process, the next eligible child was recruited for the study. No financial or material compensation was provided for the participants.

Study procedure

Enrolled students first completed a structured questionnaire including family history of KC, history of eye rubbing, allergy and parental consanguinity. Participants then underwent a comprehensive ocular assessment in a standardized screening setting within the school by trained optometrists. The examination included uncorrected, presenting and pinhole visual acuity (VA) using logMAR charts at 4m. The objective refraction was conducted using an Autorefracto-Keratometry (Auto Ref/Keratometer ARK-F). The ocular media was then scanned using a retinoscope (HEINE BETA 200) primarily to identify the presence of scissor reflex suggestive of irregular astigmatism.

All the participants underwent corneal topography using OS1000 Corneal Topographer (SBM Sistemi, Italy) and three consecutive measurements were obtained for each eye. Scans of suboptimal quality or with evident artifacts were repeated. Only high-quality and reliable scans as identified by the topographer were included in the final analysis. All topographic image analysis were conducted by a single trained optometrist to eliminate inter-examiner variability.

Criteria for classifying KC types

Participants were classified as having keratoconus (KC) or keratoconus suspect (KCS) using predefined screening (clinical and topographic) criteria (Table 1) [3, 28–31]. A diagnosis of KC was made when participants met at least two of the four clinical assessment criteria (topography, autorefractor-keratometry, retinoscopy, and refractive profile). To satisfy the topography criterion, all four targeted topographic parameters had to be present.

Participants were classified as KCS if they demonstrated a scissor reflex on retinoscopy. In addition, individuals were classified as KCS if they simultaneously met all three of the following criteria: (1) astigmatism > 1.00 Dioptre (D), (2) mean keratometry > 45.00 D, and (3) at least two of the following topographic features: asymmetric bow-tie pattern, inferior–superior (I–S) index ≥ 1 , or surface asymmetry index (SAI) ≥ 0.7 .

Statistical analysis

Data was analyzed using SPSS version 31 (IBM Cor., Armonk, NY, USA). Participant demographics were summarized using descriptive statistics (mean $\pm$ SD or frequencies). Ocular parameters between KC, non-keratoconus (non-KC) and KCS were assessed using Kruskal-Wallis test along with Mann-Whitney U test for post-hoc pairwise comparisons with appropriate adjustments for multiple testing. A binary logistic regression analysis was performed to identify independent predictors of KC. Results were reported as odds ratios (OR) and 95% confidence intervals (CI). The statistical significance was kept at $p < .05$.

Ethical considerations

Ethical approval

was granted by the College Research Committee of the College of Health Sciences, University of Buraimi under No. AY24-25COHS-083 which adhered to the tenets of the Declaration of Helsinki. Authorization to conduct the study in schools was obtained from the Directorate General of Education in Al Buraimi Governorate. Written informed consent was collected from parents or guardians before including students, and the study procedures were explained to the children before assessment.

Table 1
Criteria utilized to classify KC and KCS

Screening tests	Targeted Parameters	KC Cutt-off Value	KCS Cutt-off Value
Topography	Mean K	≥ 47.2 D	At least two out of three topographic parameters [1. Presence of asymmetric bow-tie pattern, 2. I-S index ≥ 1 , 3. SAI ≥ 0.7]
	I-S value	≥ 1.4 D	
	SAI value	1.25	
	Asymmetrical bow tie pattern	Present	
Auto-Refractokeratometry	Mean K	≥ 47 D	≥ 45 D
Retinoscopy	Scissor Reflex	Present	Present
Refractive profile	Refractive error	≥ -5.0 D and or astigmatism	Astigmatism > 1.5 D
	Irregular Astigmatism	> 1.5 D	

Results

Data from 733 schoolchildren from the Al Buraimi Governorate including its three Wilayats (Al Buraimi, Mahdha, and Al Sunaina) were analysed to identify and clinically characterize participants into normal,

KC and KCS. The demographic characteristics of the study participants are presented in Table 2. The mean age of participants was 13.95 ± 2.19 years, and students were grouped into 9–12 and 13–18 years categories. Most participants were male (67.4%) and Omani nationals (87.4%).

Twelve participants (1.6%) failed two or more screening tests (as specified in Table 1) and were classified as KC. KC prevalence was higher among males (9 cases) and in the 13–18 age group (all 12 cases). Based on the KCS criteria outlined in Table 1, 37 participants (5.0%) were classified as KCS. Prevalence was higher among females (13 cases; 5.4%) and in the 13–18 years age group (32 cases; 5.9%). KCS was more common among Omani schoolchildren (34 cases; 5.3%). Additional information is available in Table 2.

Table 2
Participant demographics and prevalence of KC and KCS ($n = 733$)

Demographics		Number <i>n</i> (%)	KC prevalence <i>n</i> (%)	KCS prevalence <i>n</i> (%)	<i>p</i> value
Nationality	Omani	641 (87.4)	11 (1.7)	34 (5.3)	0.54
	Non-Omani	92 (12.6)	1 (1.1)	3 (3.3)	
Wilayats	Al Buraimi	477 (65.1)	7 (1.5)	17 (3.6)	0.00
	Mahdha	224 (30.6)	5 (2.2)	20 (8.9)	
	Al Sunaina	32 (4.4)	0	0	
Gender	Male	494 (67.4)	9 (1.8)	24 (4.9)	0.43
	Female	239 (32.6)	3 (1.3)	13 (5.4)	
Age groups (years)	9–12	187	0	5 (2.7)	0.02
	13–18	546	12 (2.2)	32 (5.9)	
Total		733	12 (1.6)	37 (5.0)	

Table 3

Ocular parameter comparisons among KC, non-keratoconus (NKC) and KCS groups (mean and 95% CI)

Parameters	Eye	NKC (n = 687) Mean (95% CI)	KCS (n = 37) Mean (95% CI)	KC (n = 12) Mean (95% CI)	p-value (KCS/NKC)	p-value (KC/NKC)
Unaided VA (log MAR)	OD	0.18 (0.15–0.20)	0.29 (0.19–0.39)	0.33 (0.14–0.51)	.000	.001
	OS	0.16 (0.14–0.19)	0.32 (0.21–0.4)	0.34 (0.16–0.43)	.000	.005
SER (D)	OD	-0.18 (-0.37 to 0.01)	-0.67 (-0.97 to -0.36)	-1.26 (-2.32 to -0.20)	.012	.006
	OS	-0.26 (-0.36 to -0.15)	-0.74 (-1.09 to -0.40)	-1.34 (-2.50 to -0.18)	.004	.023
Astigmatism (D)	OD	-0.54 (-0.59 to -0.49)	-0.99 (-1.27 to -0.71)	-1.45 (-2.21 to -0.70)	.001	.023
	OS	-0.50 (-0.55 to -0.46)	-1.00 (-1.32 to -0.68)	-1.78 (-2.56 to -0.98)	.001	.001
Auto-Refractokeratometry (D)	OD	43.65 (43.53 to 43.77)	44.29 (43.77 to 44.82)	46.93 (45.85 to 48.02)	.024	.000
	OS	42.61 (42.10 to 43.12)	41.78 (38.35 to 45.20)	46.83 (45.98 to 47.68)	.282	.000
Topography mean K (D)	OD	45.22 (45.06 to 45.37)	46.56 (45.72 to 47.41)	49.44 (47.23 to 51.64)	.002	.000
	OS	45.26 (45.11 to 45.40)	46.23 (45.38 to 47.08)	50.19 (48.34 to 52.04)	.087	.000
SAI	OD	0.69 (0.66 to 0.73)	0.82 (0.68 to 0.96)	1.94 (0.14 to 3.74)	.126	.263
	OS	0.64 (0.61 to 0.67)	0.63 (0.48 to 0.78)	1.74 (-0.01 to 3.49)	.761	.133

NKC = Non-keratoconus, KC=keratoconus, KCS=keratoconus suspect, VA=visual acuity, SER=spherical equivalent refraction, D=dioptr, SAI=surface asymmetry index, I-S value: Superior inferior power difference, OD=Right eye, OS=Left eye

Parameters	Eye	NKC (n = 687) Mean (95% CI)	KCS (n = 37) Mean (95% CI)	KC (n = 12) Mean (95% CI)	p-value (KCS/NKC)	p-value (KC/NKC)
			0.78)	3.49)		
I-S value	OD	0.15 (0.12 to 0.19)	-0.03 (-0.27 to 0.22)	1.36 (-0.51 to 3.22)	.420	.594
	OS	0.21 (0.07 to 0.34)	0.08 (-0.11 to 0.27)	1.22 (-0.34 to 2.79)	.669	.148
NKC = Non-keratoconus, KC=keratoconus, KCS=keratoconus suspect, VA=visual acuity, SER=spherical equivalent refraction, D=dioptr, SAI=surface asymmetry index, I-S value: Superior inferior power difference, OD=Right eye, OS=Left eye						

Table 4
Binary logistic regression predicting KC and risk factors

Predictor variables	KCS				KC			
	p	df	OR Exp[B]	95% CI for OR	p	df	OR Exp[B]	95% CI for OR
Allergy – occasional	.056	1	3.30	(.97 to 11.21)	.084	1	.080	(.005 to 1.40)
Allergy – frequent	.002*	1	14.28	(2.59 to 78.69)	.998	1	.000	.000
Eye rubbing – occasional	.083	1	2.92	(.87 to 9.83)	.368	1	.280	(.02 to 4.48)
Eye rubbing – frequent	.038*	1	.166	(.03 to .91)	.020*	1	13.60	(1.51 to 122.28)
Consanguinity	.237	1	.496	(.16 to 1.59)	.021*	1	21.77	(1.61 to 294.79)
Age	.731	1	.956	(.74 to 1.24)	.539	1	1.15	(.74 to 1.81)
Gender	.238	1	1.99	(.63 to 6.25)	.406	1	.386	(.04 to 3.66)

p<.05*

Comparisons among NKCS, KC, KC were performed using the Kruskal–Wallis test due to non-normal data distribution. When a significant omnibus effect was detected, post hoc pairwise comparisons were conducted using the Mann–Whitney U test. Results are presented as mean values with 95% confidence intervals for right (OD) and left (OS) eyes (Table 3).

A significant difference between groups were observed for unaided visual acuity (logMAR) in both eyes ($p < 0.001$), spherical equivalent refraction ($p < 0.05$) and astigmatism ($p < 0.01$). The post hoc analyses showed poorer visual acuity, increasing myopia and higher astigmatism in the KCS and KC groups compared to NKC group. Average keratometry also differed significantly ($p < 0.05$); in the OD, both KCS ($p = 0.024$) and KC ($p < 0.001$) had steeper corneas than NKC, while in the left eye only KC remained significantly steeper ($p < 0.001$). There was no significant differences observed for surface asymmetrical or irregularity indices ($p > 0.05$), though greater variability was seen in the KC group. Although mean values were higher in the KC group, wide confidence intervals suggest substantial variability, likely due to small sample size (Table 3)

A binary logistic regression was used to identify independent predictors of keratoconus. The model included gender, age, scissor reflex, allergy status, consanguinity, and eye rubbing as covariates (Table 4). The regression analysis identified scissor reflex as the strongest predictor of both KCS (OR = 848.52, 95% CI: 168.03–4284.93; $p < 0.001$) and KC (OR = 120.65, 95% CI: 16.98–857.25; $p < 0.001$). In KCS, frequent allergy shows increased risk (OR = 14.28; $p = 0.002$) along with frequent eye rubbing ($p < 0.05$). In KC, consanguinity was a significant predictor (OR = 21.77; $p = 0.021$), along with frequent eye rubbing (OR = 13.60; $p = 0.020$). Age and gender were not significant in either model ($p > 0.05$), highlighting distinct yet overlapping risk profiles across disease stages.

Discussion

This study represents the first population-based investigation of school children in the Sultanate of Oman aimed at estimating the prevalence of KC. It revealed a comparable prevalence rate reported from the region. Consanguinity emerged as a significant predictor for KC, in addition to frequent eye rubbing.

Although the overall reported prevalence of KC in this study was 1.6%, it is important to note that no cases were identified among children aged 9–12 years. All cases occurred in the 13-18-year age group. When analysis is restricted to this subgroup, the effective prevalence becomes 2.2% (12/546), closely aligning with reports from comparable age groups in Saudi Arabia (2.75%) and the United Arab Emirates (2.7%). These findings reinforce evidence that KC prevalence in Middle Eastern adolescents is higher than that reported in western populations.

This age-specific pattern is consistent with prevalence estimates reported among young adults in the region. Studies have documented rates of 2.34% among young volunteers in Israel [32], 3.3% among medical students in Lebanon [33], 2.5% in a population-based study from Iran [34], 3.18% among Israeli college students [35], 1.5% among Palestinian youth [36], 2.4% among university students in Turkey [37], and 1.43% among Syrian university populations [38]. Taken together, these findings reiterate KC as an important ocular health burden affecting adolescents and young adults across the Middle East, underscoring the need for proactive school and clinic-based screening in the region.

Consanguinity and frequent eye rubbing were both identified as significant predictors of keratoconus (KC) in this study; while the association with eye rubbing aligns with global evidence [20, 39], the

prominence of consanguinity reflects patterns more commonly reported in Middle Eastern populations [19, 40, 41]. Given the high prevalence of consanguineous marriages in the Middle East, it is probable that consanguinity contributes substantially to the regional burden of KC. Across the Middle East and North Africa, an estimated 20–56% of marriages are consanguineous, significantly higher than the global average of 1–9% [42, 43]. Rates of approximately 50% or higher have been reported in several countries, including Saudi Arabia, Qatar, the United Arab Emirates, Oman, Jordan, and parts of Egypt, signifying a potential role of genetic susceptibility in KC within this region [44].

The scissor reflex was identified as the most significant predictor of KC and KCS, consistent with previous reports [28, 29, 45, 46]. Among individual screening measures, scissor reflex demonstrated the highest Youden index (0.44), indicating greatest discriminating ability for identifying KC and KCS. The observation that nearly two-thirds of identified KC cases exhibited scissor reflex highlights the importance of optometrists in early detection of KC [28, 47, 48]. It also underscores the value of retinoscopy as a screening tool: the retinoscope is low cost, portable, quick and easy to administer, and requires minimal training, making it well suited for school-based vision screening programs [28].

The early onset of KC in younger individuals suggests its progression with age, signifies the importance of early detection and timely intervention in children (36). Participants identified as at risk in the study were referred to a tertiary care hospital for further evaluation and early intervention.

This study has several limitations. First, the topographer utilized for screening did not provide posterior corneal profile; therefore, children exhibiting only posterior corneal steepening may have been missed, potentially causing an underestimation of prevalence. Second, the relatively smaller number of KC cases limited the statistical power regression analyses and reduced the precision of confidence interval estimates. Third, the information on eye rubbing and allergy was obtained through self- or parent reports. This might have resulted in recall bias.

These observations highlight the importance of incorporating detailed KC screenings into school vision programs. Incorporating corneal tomography into the battery of tests may enhance the accuracy of early detection and screening strategies for keratoconus.

Conclusion

The prevalence rate of keratoconus reported in this study is consistent with the reports from the Middle Eastern region and confirms a higher burden compared to the west. The identification of consanguinity as a significant predictor, matching the regional patterns, signifies the need for greater attention to genetic counselling and risk awareness. The strong predictive values of the scissor reflex support the inclusion of retinoscope to screen the refractive media. These findings support the development of a standardized framework for early detection and screening of keratoconus in the country.

Declarations

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation

During the preparation of this work the author(s) used PAPERPAL to improve language clarity and readability. After using this tool, the author(s) reviewed and edited the content as needed and took full responsibility for the content of the published article.

Competing interests

The authors declare no competing interests.

Author Contribution

MZ conceived and designed the study. All authors collected the clinical data. MZ, GV, and BN analyzed and interpreted the patient data. MZ and BN prepared the manuscript draft, while JA and GV critically revised the manuscript for significant intellectual content. All authors reviewed and approved the final manuscript.

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