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Aetiology of climatic droplet keratopathy and pterygium

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SUMMARY The association of various personal, occupational, and environmental factors with climatic droplet keratopathy and pterygium was examined in a group of Australian Aborigines. Climatic droplet keratopathy was seen especially in aboriginal males who had worked as stockmen for more than 20 years. Although no definite association with a single causal factor could be made, there is circumstantial evidence for the importance of ultraviolet radiation. Pterygium was more commonly seen in those who worked outside, and it was positively correlated with lower latitudes and high ultraviolet levels.

In 1965 Freedman[1] described a bilateral acquired corneal degeneration occurring in indigenous populations in Labrador and Northern Newfoundland, which he called Labrador keratopathy. This keratopathy was characterised initially by the presence of small droplets at the level of Bowman's membrane, and these progressed to give a haze and eventually were sometimes associated with the development of yellow nodules.

This keratopathy resembles that described by Zanettia,[2] Falcone,[3] and Bietti *et al.*[4] in the Dahlak Islands in the Red Sea, Somalia, Eritrea, and Saudi Arabia. The keratopathy seen in the Dahlak Islands was examined further by Rodger.[5] He found that although the keratopathy showed the same course of progression with age as was seen in Labrador, more people were found with the disease's advanced stage that included the opacification of the whole stroma and sloughing of nodules.

Since then Fraunfelder and his associates have described a condition that they have called 'spheroidal degeneration' of the cornea and conjunctiva.[6–9] This condition is characterised by small golden or yellow globules. It may be a primary condition of an otherwise normal cornea or conjunctiva, or it may be secondary to other ocular pathology, especially absolute glaucoma, trauma, or pterygia. Garner *et al.*[10] reported these golden droplets in 6% of patients presenting to an eye clinic in England.

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Many have considered that the 2 conditions are the same environmentally induced corneal degeneration.

It would appear, however, that 2 different conditions are being described. The condition that Freedman and Rodger described appears to be related to severe climatic conditions and starts as a fine frosting of clear vesicles at the level of Bowman's membrane. It is more severe in the Red Sea littoral, where it may progress to total stromal involvement and scarring. The second condition, described by Fraunfelder and associates, is a milder degenerative condition characterised by golden globules. It is more often seen as a mild ageing process in otherwise normal eyes, or it may develop secondarily to severe corneal disease, ocular trauma, or glaucoma, or even as a secondary phenomenon in the degeneration described by Rodger and Freedman. That these conditions may be different has been alluded to by Johnson and Ghosh[11] and by Anderson and Fuglsang.[12] It is therefore proposed to differentiate between the 2 conditions, and (1) to refer to the specific condition described by Freedman and Rodger as 'climatic droplet keratopathy' (Labrador keratopathy), as suggested by Freedman[13 14]; and (2) to use Fraunfelder's terminology of 'speroidal droplet degeneration' for the condition that in some cases may be an ageing phenomenon and sometimes may be secondary to other corneal pathology. It is not proposed, however, to enter further into the argument about nomenclature of these conditions.

The aetiology of climatic droplet keratopathy is unknown. An environmental cause has been proposed for this condition from the time it was first described.[1 5] An environmental cause is thought likely because the keratopathy has a relatively uniform clinical appearance and a striking regional distribution. Attention has been drawn in particular to ultraviolet light, as all the areas in which this keratopathy has been found have high levels of ultraviolet light.

In northern Canada and in the other areas studied by Forsius,[15] an inverse relation was found between the prevalence of climatic droplet keratopathy and the degree of shelter from sunlight provided by trees. This variation with shelter from the sun was also noted by Anderson and Fuglsang[12] in West Africa. Rodger *et al.*[16] measured the amount of ultraviolet light present in the Dahlak Islands and found it to be 6 to 7 times greater than in England.

Bietti *et al.*[4] suggested that drying of the cornea may be the initiating factor, because the patients he saw lived in hot arid conditions. Although the arctic regions of Canada are by no means hot, they share with the desert a very low humidity, which in the arctic approaches zero level in winter. Wind is also a factor that may affect corneal drying and can lead to particulate injury from dust or driven snow, and such trauma has been implicated as an aetiological factor. As each of these latter factors (low humidity and windborne microtrauma) is also less severe in wooded areas, the case for ultraviolet light as the causative agent—which is based on regional variation—becomes less strong. It is of interest that those who have looked at the tear film have not found any abnormalities.[4 5 13 14 17 18]

The finding of cases in South Africa[19] and in south-eastern USA[20] would, however, support the theory of ultraviolet light, which is at present the most widely held. Therefore the conditions most likely to lead to the development of this keratopathy would appear to be aridity, intense sunshine, and windborne particles. The relative importance of sunshine or ultraviolet radiation has not been examined fully.

Ringland Anderson[21] was the first to try to relate the geographical distribution of pterygium to local meteorological factors. His data, which covered most of Australia, dealt with the prevalence of surgery for the removal of pterygium. He concluded that the most likely factor influencing the frequency of pterygium was corneal drying.

Others have also suggested that pterygia occur as the result of disruption of the tear film either by rapid evaporation or microtrauma from microparticles of dust.[22–25] Cass (personal communication) also suggested that irritation from fires and dust is important. However, no tear film abnormalities have been found in people with pterygia.[18 26]

Cameron,[27] in his monograph on pterygium, considered the world distribution of this condition. He found that although countries that are hot, dry, and dusty had a higher prevalence of pterygium, there were other areas that, although hot, were neither dry nor dusty and yet also had a high prevalence of pterygium. The common factor appeared to be latitude, and he related this to ultraviolet irradiation, which varies with latitude. He postulated that ultraviolet light damages Bowman's membrane and causes a thickening and hyperplasia in the subconjunctival connective tissues, and that these combined changes result in pterygium. While the probable role of ultraviolet light in the initiation of pterygium is now generally accepted, there has been no direct evidence linking ultraviolet light and pterygium.

The following study investigated the role of a number of personal and environmental factors in the causation of these 2 conditions. This study was conducted as a separate study in conjunction with the routine field work performed by the National Trachoma and Eye Health Programme (NTEHP).

Patients and methods

The Aborigines examined in this study came from one of 2 groups. Firstly, any Aborigine whose best corrected acuity was 6/60 or less in either eye was included in the study together with the next Aborigine to be seen who was of the same sex, whose age was in the same decade, and who had corrected vision of 6/12 or better in both eyes.[28] 312 people were included in these groups. Secondly, 82 Aborigines were selected by examining 50% of the Aborigines over the age of 30 in two aboriginal communities. The sample was drawn randomly after the population had been enumerated.[29] In some cases these 2 groups overlapped in that some of those in the prevalence study (the second group) were also included in the study of blindness (the first group). A total of 350 Aborigines over the age of 30 are included in this study.

HISTORY

A detailed history including age, sex, tribe, and the type and duration of any previous occupation was obtained, together with details of where the patient had spent most of his or her life (residence). A history of both alcohol consumption and ocular trauma was also sought. In every case the questions were asked in a standard order and in the same way. A methodology trial showed that these questions were answered consistently.[28]

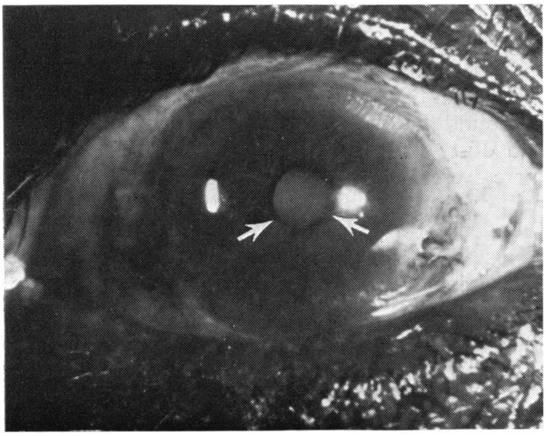

Fig. 1 *Grade 2 climatic droplet keratopathy. Fine droplets lying at the level of Bowman's membrane in the area of the interpalpebral fissure extend over the central cornea. Their presence is shown by the blurring of the underlying iris details and of the pupillary margin (between arrows).*

Fig. 2 *Grade 3 climatic droplet keratopathy with a dense accumulation of droplets and reduction of visual acuity. Clear areas of lacunae are seen centrally.*

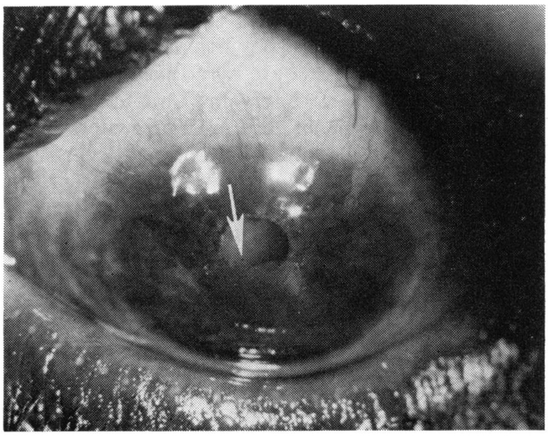

Fig. 3 *Grade 4 climatic droplet keratopathy with extensive fine droplets covering the exposed cornea. Larger golden yellow droplets are seen immediately above this band overlying the pupil (arrow). This eye also has extensive trachomatous pannus and Herbert's pits, nuclear sclerosis, pseudoexfoliation, and a small pterygium which is not well shown.*

EXAMINATION

Visual acuity was tested with a standard chart, usually an illiterate E chart. Best corrected vision was recorded. Each patient was examined for signs of trachoma with a loupe and suitable illumination. Trachoma was graded according to the severity of 7 signs according to the NTEHP grading protocol.[28] After the grading for trachoma, all people were examined with a slit-lamp and with direct and indirect ophthalmoscope.

CDK was graded as follows: grade 1, peripheral changes present; grade 2, changes across the pupillary axis; grade 3, changes leading to a decrease in visual acuity; grade 4, the presence of nodules (Figs. 1–3).[11] The extent of pterygia was recorded in millimetres.

ANALYSIS

To facilitate statistical comparison of the presence and severity of trachoma an index called 'Trachoma Scarring Index' was used.[28] This index draws on the severity of the individual signs of structural change or cicatrisation caused by trachoma, but lends more weight to the presence of multiple abnormalities. Individuals are classified by their worse eye.

Meteorological data were obtained from publications of the Bureau of Meteorology.[30–32] These parameters were then recorded for the location where each patient had spent most of his or her life (residence). The mean daily maximum temperature, the mean daily relative humidity at 1500 h, the evaporation rate, and the average daily global radiation were recorded for the month of January and for the year. The average daily hours of sunlight and the median annual rainfall were also recorded. The amount of ultraviolet B radiation for each location was determined from maps prepared by calculation, with verification using observed data.[33] The latitude, longitude, and altitude of each place of residence were also recorded.

The data were coded on specially prepared clinical sheets and transferred to computer tape. A detailed analysis of possible associations between the personal, environmental, and general variables

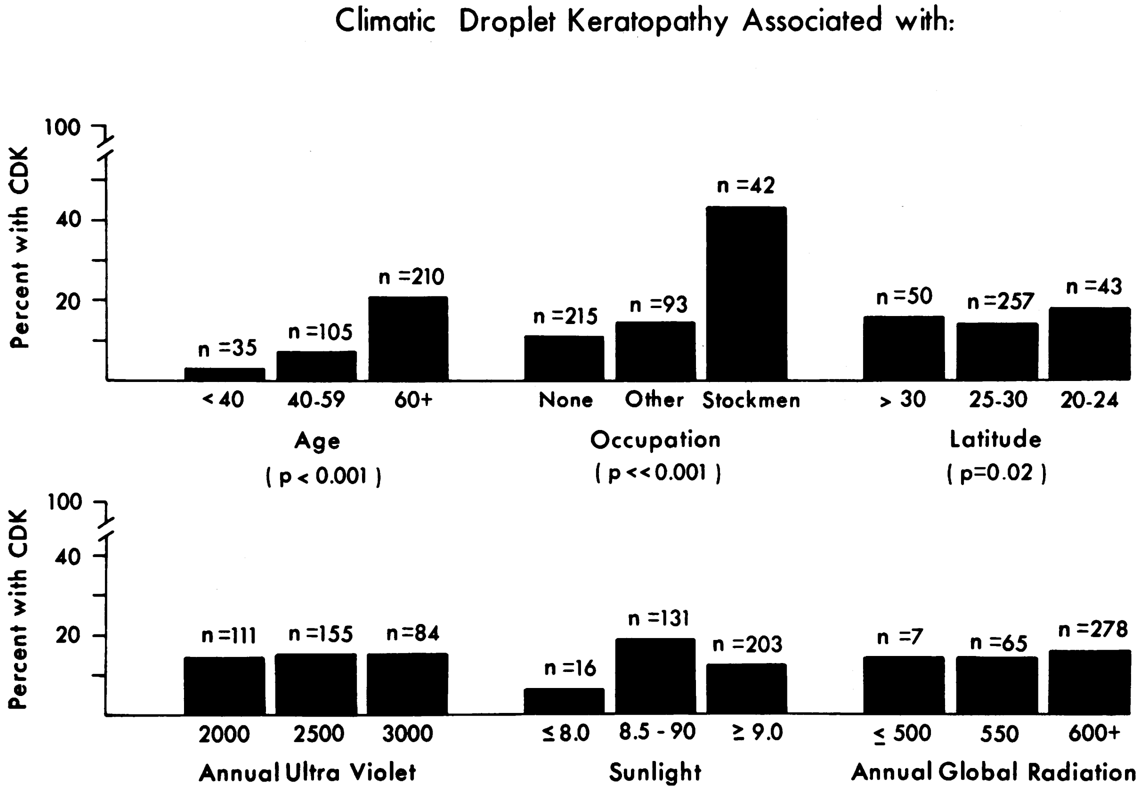

Fig. 4 *Histograms showing the prevalence of climatic droplet keratopathy in 350 Aborigines by age (years), occupation, latitude (degrees), annual mean ultraviolet B radiation (minimal erythema doses), annual mean daily hours of sunlight, and annual mean daily total global radiation ($mW/h/cm^2$).*

and the presence or absence of CDK and pterygium was conducted on the Unix time-sharing PDP 11/45 computer at the Johns Hopkins Hospital. The test of statistical significance used throughout was the chi-square test. For simplicity only the P values are presented, but it must be remembered that the associations of many variables were examined.

Results

CLIMATIC DROPLET KERATOPATHY

In the 350 individuals examined 52 people (43 males and 9 females) with CDK were seen. The sex correlation was very significant ($P<<0{\cdot}001$). CDK was found more often in the elderly (Table 1, Fig. 4). CDK was strongly related to a history of occupation as a stockman ($P<<0{\cdot}001$) (Table 1, Fig. 4). However, no difference was seen in the frequency of CDK between the other groups of outdoor workers, and people with other jobs, and those who had not worked. Among the stockmen a strong correlation was seen between CDK and the length

Table 1 *Distribution of climatic droplet keratopathy by age and occupation in 350 Aborigines**

	Climatic droplet keratopathy		
	Present	*Absent*	*Total*
Age (years)			
0–39	1	34	35
40–59	7	98	105
60 or more	44	166	210
Occupation			
None	23	192	215
Stockman	18	24	42
Station hand	5	33	38
Labourer	2	8	10
Other	4	41	45
Total	52	298	350

*χ^2 test: Age $P<<0{\cdot}001$; occupation (stockmen vs. rest) $P<<0{\cdot}001$.

of time worked as a stockman. None of 8 who had worked as stockmen for less than 20 years had CDK, whereas 16 of 34 who had done that work more than 20 years had CDK (P=0·006).

No relation existed between the severity of trachoma and the presence of CDK. No relation was found between CDK and latitude (Table 2). Stockmen are analysed separately, as the prevalence of CDK was high in this group. CDK was seen more often in areas with 9 or more hours of sunshine per day (annual mean daily hours of sunshine) than in areas with $8\frac{1}{2}$ or less hours of sunshine per day (Table 2, Fig. 4). This correlation was significant for the group as a whole (P=0·05) but not significant for stockmen.

Annual total global radiation was not related to the presence of CDK (Table 3, Fig. 4). There was no significant correlation with levels of ultraviolet radiation, either for January or for the year (Table 3, Fig. 4). This was true for both the group as a whole and for stockmen.

A trend existed for CDK to be found more commonly in areas with lower maximum temperatures in January (37°C or less) than in areas with maximums of 38°C and higher (Table 4), though no such trend was seen with annual mean temperatures. No significant correlation existed between CDK and annual rainfall (Table 4), although CDK tended to occur more often in areas with higher rainfall (P=0·08 for both groups).

The annual evaporation rate was not correlated with the presence of CDK in the group as a whole, but among stockmen CDK was more commonly seen in areas with lower annual evaporation rates (P=0·04). For both stockmen and the group as a whole CDK was seen more often in areas with lower January evaporation rates (Table 5). A high relative humidity in January was associated with a higher incidence of CDK. A similar but not significant trend existed in relation to annual humidity.

When those men who had worked as stockmen for more than 20 years were examined as a separate group, no causative differences were found between those with and without CDK. In all, there were 34 men in this group, 18 with CDK and 16 without.

Table 2 *Distribution of climatic droplet keratopathy by latitude and mean daily hours of sunshine for the group as a whole and for the 42 stockmen**

	CDK—Whole group			*CDK—stockmen*		
	Present	*Absent*	*Total*	*Present*	*Absent*	*Total*
Latitude (degree)						
20–24	8	35	43	3	3	6
25–30	36	221	257	11	19	30
30 or more	8	42	50	4	2	6
Sunshine (hours)						
8·5 or less	17	61	78	7	8	15
9·0 or more	35	237	272	11	16	27
Total	52	298	350	18	24	42

*χ^2 test: Sunshine whole group; P=0·05; stockmen; not significant.

Table 3 *Distribution of climatic droplet keratopathy by mean daily total radiation for January ($mW/h/cm^2$) and ultraviolet radiation (mean erythemal doses) for the group as a whole and for the 42 stockmen*

	CDK—Whole group			*CDK—Stockmen*		
	Present	*Absent*	*Total*	*Present*	*Absent*	*Total*
Global radiation						
800 or less	31	118	149	12	6	18
more than 800	21	180	201	6	18	24
UV dosage						
January						
4000 or less	32	177	209	13	17	30
4500 or more	20	121	141	5	7	12
Year						
2000 or less	15	96	111	5	5	10
2500	24	131	155	7	9	16
3000 or more	13	71	84	6	10	16
Total	52	298	350	18	24	42

Table 4 *Distribution of climatic droplet keratopathy by mean daily maximum temperature for January and mean annual rainfall for the group as a whole and for the 42 stockmen**

	CDK—Whole group			*CDK—Stockmen*		
	Present	*Absent*	*Total*	*Present*	*Absent*	*Total*
Temperature (°C)						
37 or less	38	166	204	14	11	25
38 or more	14	132	146	4	13	17
Annual rainfall (mm)						
200 or less	15	114	129	6	7	13
200–250	25	148	173	9	16	25
250 or more	12	36	48	3	1	4
Total	52	298	350	18	24	42

*χ^2 test: Temperature—whole group, P=0·02; stockmen, P=0·04. Rainfall—whole group, P=0·08; stockmen, P=0·08.

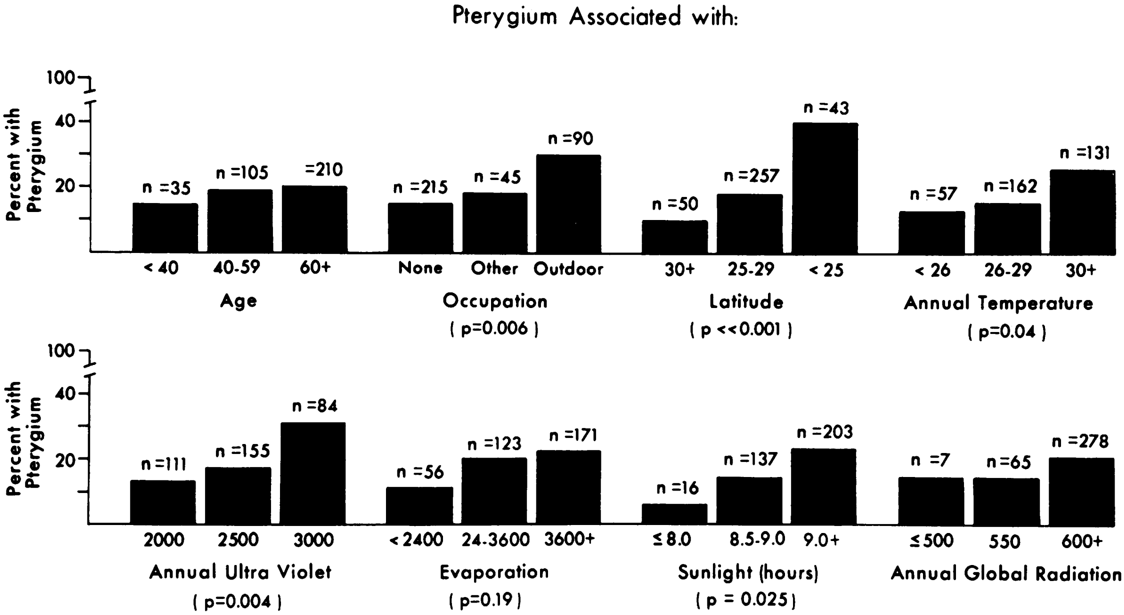

Fig. 5 *Histograms showing the prevalence of pterygium in 350 Aborigines by age (years), occupation, latitude (degrees), annual mean daily maximum temperature (°C), annual mean ultraviolet B radiation (minimal erythema doses), annual mean evaporation rates (mm), annual mean daily hours of sunlight, and annual mean daily total global radiation (mW/h/cm²).*

It may be that the small numbers in these groups obscured any trends or associations that may have been present. There was no tribal bias in the distribution of CDK, nor was there a clustering in relation to places of examination. The factors examined were: age, latitude, altitude, alcohol intake, ocular trauma, and the annual and January values for ultraviolet radiation, maximum temperature, rainfall, sunshine, global radiation, evaporation rate, and relative humidity.

Table 5 *Relation between climatic droplet keratopathy and total evaporation for January and relative humidity for January for the whole group and for the 42 stockmen**

	CDK—Whole group			*CDK—Stockmen*		
	Present	*Absent*	*Total*	*Present*	*Absent*	*Total*
Evaporation (mm)						
250–500	39	152	191	14	10	24
550–600	13	146	159	4	14	18
Relative humidity (percentage)						
30 or less	18	162	180	4	16	20
30–40	17	66	83	7	4	11
40 or more	17	70	87	7	4	11
Total	52	298	350	18	24	42

*χ^2 test: Evaporation, whole group, P=0·001; stockmen, P=0·02. Humidity, whole group, P= 0·03; stockmen, P=0·02.

PTERYGIUM

Sixty-seven people with pterygium were seen; there were 31 males and 36 females. There was no sex correlation nor was pterygium more common with increasing age (Table 6, Fig. 5). Such trends may have been masked by the matching used in the case control study. Pterygium was associated with certain occupations (Table 6, Fig. 5). It was seen more commonly in the 3 groups of outdoor workers (stockmen, station hands, and labourers) than in those with other occupations or those who had not worked. No significant difference existed between the 3 outdoor groups.

A history of alcohol intake, previous ocular trauma, and the severity of trachoma, was not related to the presence of pterygium.

A significant association was found between latitude and pterygium (Table 7, Fig. 5). Pterygia were seen more often in those from lower latitudes (P<<0·001). Pterygium was also associated with longer hours of sunlight (Table 7, Fig. 5) (P=0·025) and high levels of total global radiation in January (Table 8, Fig. 5) (P=0·04), but it was not associated with the annual global radiation levels.

Table 6 *Distribution of pterygium by age and occupation in 350 Aborigines**

	Pterygium		
	Present	*Absent*	*Total*
Age (years)			
0–39	5	30	35
40–59	20	85	105
60 or more	42	168	210
Occupation			
None	32	183	215
Stockman	10	32	42
Station hand	12	26	38
Labourer	5	5	10
Other	8	37	45
Total	67	283	350

*χ^2 test: occupation, outdoor workers vs. rest, P=0·006; 4 degrees of freedom, P=0·01.

Table 7 *Distribution of pterygium by latitude, annual mean ultraviolet B radiation (mean erythemal doses), and annual mean daily hours of sunshine in 350 Aborigines**

	Pterygium		
	Present	*Absent*	*Total*
Latitude (degrees)			
24 or less	17	26	43
25–29	45	212	257
30 or more	5	45	50
Sunshine (hours)			
9·0 or less	20	127	147
9·5 or more	47	156	203
UV dosage			
2000	14	97	111
2500	27	128	155
3000	26	58	84
Total	67	283	350

*χ^2 test: Latitude, P<<0·001; sunshine, P=0·025; UV, P=0·004.

A significant association existed between the presence of pterygium and annual mean ultraviolet radiation levels (Table 7, Fig. 5) (P=0·004). When those over the age of 40 were examined, the relation between ultraviolet radiation and pterygium was increased (P=0·001), but the ultraviolet radiation in the month of January was not significantly related to the presence of pterygium in either age group.

A significant relation was also seen between pterygium and a higher mean annual maximum temperature (Table 9, Fig. 5), and a trend with higher temperatures in January (P=0·125). This may suggest that a continually hot climate is more important in pterygium formation than the extremes of temperature. Pterygia were not associated with the annual rainfall, or the evaporation rate in January. However, pterygium tended to be more common in areas of high annual evaporation rates; those areas with evaporation rates of 2200 mm or less had fewer pterygia than those with evaporation rates of 2400 mm or more (Table 9). A trend also existed for pterygium to be seen less often in areas with an annual relative humidity in the range of 40–59% than in areas with a higher or lower annual relative humidity (Table 9).

Table 8 *Relation between pterygium and mean daily total global radiation (mW/h/cm²) for January and for the year in 350 Aborigines**

	Pterygium		
Global radiation	*Present*	*Absent*	*Total*
January			
less than 800	21	128	149
800 or more	46	155	201
Annual			
less than 550	10	62	72
550 or more	57	221	278
Total	67	283	350

*χ^2 test: P=0·04 (January); annual, not significant.

Table 9 *Relation between pterygium and annual mean temperature, annual mean daily evaporation rate, and also annual mean relative humidity in 350 Aborigines**

	Pterygium		
	Present	*Absent*	*Total*
Temperature (°C)			
25 or less	7	50	57
26–29	26	136	162
30 or more	34	97	131
Evaporation			
2200 or less	6	50	56
2400–3200	24	99	123
3600 or more	37	134	171
Humidity			
40 or less	33	112	145
40–49	16	109	125
50 or more	18	62	80
Total	67	283	350

*χ^2 test: Temperature, P=0·004; evaporation, P=0·19; humidity, P=0·08.

Discussion

Because of the methods used to obtain the groups for this study, no inference can be drawn about the prevalence of CDK or pterygium in the population studied, although an investigation into the role that personal and environmental factors play in causation of these 2 conditions is valid.[29]

Good descriptions of the clinical appearance of CDK have been given by Freedman,[13] Anderson and Fuglsang,[12] and Johnson and Ghosh.[11] The changes seen in Aborigines were as described by these authors.

Only a few detailed studies of the prevalence of CDK have been reported.[15 29 34 35] While there are some differences in the distribution and severity of CDK in the areas studied, these differences are probably related to variation in occupation and exposure. Isolated reports of cases have also come from other parts of the world.[13 17 36–40] However, many of these cases may have been spheroidal droplet degeneration rather than CDK itself.

The first report of this condition in Australia was made by McGuinness *et al.*[41] They reported 51 cases seen in aboriginal males, all of whom had been stockmen for at least 20 years. Hollows[42] found the prevalence to be 50% in the middle-aged men, but it was rare in females. Freedman[13] also reported 2 cases from Australia. Taylor[29] reported a prevalence of 41% for aboriginal men over the age of 45 and 8% for aboriginal women aged 45 or more.

A number of reports documenting the pathology of climatic droplet keratopathy have now been published. The most comprehensive is that by Klintworth.[43] The most significant contribution to the understanding of the pathology of this puzzling condition has been made recently by Johnson and Overall,[44] who studied cases from Labrador with histochemical and antibody-labelling techniques. They demonstrated by immunoperoxidase studies that the droplets accumulate in the areas of the highest plasma-protein concentration. This, together with the fibrinoid tinctural properties and the strong evidence against a keratin or collagen derivation as shown by both Johnson and Overall and also by Klintworth,[43] suggests that the droplets are likely to be denatured plasma proteins.

In our study a number of interesting correlations were found between CDK and environmental factors. The association between occupation as a stockman for more than 20 years and climatic droplet keratopathy that McGuinness *et al.*[41] posed was strongly confirmed in this study. However, the analysis failed to shed any direct light on possible causative factors. In one sense it has clouded the issue by showing negative trends for some of the factors commonly regarded as potentially causative. This is probably because no account was taken of the variation in exposure to the different environmental factors that could occur in different groups. This study used the data available for the environmental parameters of each area and it did not measure the variation in exposure that does occur in those with different occupations.

No direct association was found between CDK and ultraviolet radiation or other factors likely to affect ultraviolet or other radiation levels such as latitude, hours of sunlight, or global radiation. In fact, there was a tendency for CDK to occur more often in areas with lower global radiation.

No association was found between CDK and factors indicative of dry or arid environments. In fact, the reverse trends were seen, although they were usually not statistically significant. CDK was found less commonly in arid areas with low rainfall, high evaporation rates, and low relative humidity. Although the role of microtrauma from dust or sand particles was not specifically examined, and data for wind strength and direction and dust-storm frequency were not available, the lack of association between the conditions that usually define areas likely to have dust storms, such as low rainfall, suggest that microtrauma is not likely to be a factor in causing CDK.

One explanation for the relatively lower prevalence of climatic droplet keratopathy in the more inhospitable climates may have been that these areas were also unsuitable for cattle raising, and therefore there would not be stockmen working in these areas. It was for this reason that the subgroup of those stockmen who had worked for more than 20 years was examined. Although the numbers were not large in this group, no direct evidence emerged that would indicate a causative factor for CDK. Except for occupation, the study was unable to substantiate the importance of any of the factors previously thought to be associated with the development of climatic droplet keratopathy.

By observation of stockmen at work the potential causative factors that seem relevant are exposure to sunlight (including ultraviolet light) and to dust. Aboriginal stockmen differ from the European stockmen in that the Europeans do not usually spend more than a few years continuously working with cattle in the outback. After a few years a European usually will either move elsewhere or become a station manager, and therefore will not spend as many years continuously moving and mustering cattle. Aboriginal stockmen differ from other Aborigines in that they usually work through the heat of the day, often in shadowless plains, and are therefore not able to rest under the shade of a tree, wiltja, or shed as other Aborigines are able to do whether they are employed or not. Exposure to dust occurs particularly at the time of yarding. While it is true that aboriginal children are often around the cattle mustering yards, they do not spend long hours there, and women are rarely seen there. Again, these tasks are performed mainly by the aboriginal stockmen, only sometimes being overseen by a European manager.

Although it is one thing to measure the environmental factors as they affect an area, it is another thing to measure the actual exposure that various individuals receive. No data are available for the amount of ultraviolet radiation received by those working as stockmen, as compared to other people living in the same area. It would appear that the environmental ultraviolet radiation is sufficient to cause climatic droplet keratopathy anywhere in the areas studied if a person receives sufficient outdoor exposure. It would appear that (as a group) stockmen who work continuously through the hottest part of the day and therefore receive the longest ultraviolet exposure are the only ones who receive sufficient radiation to induce the changes recognised clinically as CDK.

A possible mechanism of action of ultraviolet radiation has been proposed by Johnson and Overall.[44] They have suggested that plasma proteins, especially albumin, IgG, and IgA, are affected or denatured by ultraviolet radiation as they diffuse through the cornea. This results in their deposition and accumulation. Because these proteins are most concentrated in the corneal periphery, it is not surprising that their accumulation should be first seen in that area. The distribution in the palpebral fissure is entirely consistent with a direct radiation effect, as is the initial superficial location.

The amount of radiation a person receives is likely to be even more relevant if the ocular changes in CDK noted by Johnson and Overall[44] do in fact represent altered plasma proteins. It would then follow that the longer the exposure to ultraviolet radiation, the more altered protein would accumulate, leading eventually to those changes recognised clinically as CDK. Further, the more continuous the exposure, the less time there is available for reabsorption of altered proteins or the possibility of a 'dark repair' process to clear the deposits during times of reduced exposure or at night.

One must conclude that, although it is not possible to identify with certainty the causative factor in climatic droplet keratopathy, it is almost surely a result of environmental exposure. There is strong circumstantial evidence that ultraviolet radiation is the causative factor.

The relation between latitude and pterygium proposed by Cameron[27] was confirmed. The correlation seen with ultraviolet B radiation had been postulated before but had not been previously demonstrated. Anderson[21] postulated a causal relation between temperature and pterygium, and this study also showed a weak association between annual maximum temperature and pterygium. A trend for pterygium to be associated with higher evaporation rates was also found, although a clear relation did not exist between pterygium and humidity. The association between hours of sunlight and the global radiation in general may well represent a secondary association of these factors to latitude and ultraviolet radiation.

Following examinations conducted in Finland, Lapland, Iceland, Greenland, Northern Canada, Alaska, and Cheremis (USSR) Forsius suggested that, for pterygium to develop, a low humidity and the presence of microparticles were required as well as sufficient ultraviolet light, whereas CDK would develop in areas of high humidity and without many microparticles.[15]

Garner *et al.*[10] however, came to an opposing conclusion in that they considered that climatic extremes and trauma from dust or ice particles resulted in CDK and that sun exposure without microtrauma by dust caused other lesions, particularly pinguecula and, by inference, pterygium.

Wong[45] has suggested the possibility of a pterygium angiogenesis factor which develops following repeated irritation along the corneal-limbal junction. The presence of this factor leads to the formation of pterygium. While he examined the role of such a factor, he did not inquire into its origin. It may well be that prolonged ultraviolet exposure causes histological changes in the proteins of Bowman's membrane[27] and that these altered proteins can then act as the stimulating factor.

The present study would indicate that the development of pterygium is indeed related to ultraviolet exposure and that pterygia are more likely to develop in a hot dry environment. Further, while it is not possible clearly to identify the aetiological factors for CDK, clear evidence of the environmental nature of this condition is shown, and circumstantial evidence would implicate ultraviolet radiation.

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