Retinal nerve fibre layer thickness of black and Indian myopic students at the University of KwaZulu-Natal

Authors:
Chanel Murugan[1]
Bomikazi Z. Golodza[1]
Kaveshni Pillay[1]
Brightness N. Mthembu[1]
Praneal Singh[1]
Sibusiso K. Maseko[1]
Siddeeqa Jhetam[1]
Nishanee Rampersad[1]

Affiliations:
[1]Discipline of Optometry, School of Health Sciences, University of KwaZulu-Natal, Westville Campus, South Africa

Correspondence to:
Siddeeqa Jhetam

Email:
jhetams@ukzn.ac.za

Postal address:
Private Bag X54001, Durban 4000, South Africa

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Aim: To compare retinal nerve fibre layer (RNFL) thickness in black and Indian myopic students at the University of KwaZulu-Natal.

Method: Eighty (40 black and 40 Indian) participants of both genders and aged between 19 and 24 years (mean and standard deviation: 21 ± 1.7 years) were included in the study. Refractive errors were assessed with the Nidek AR-310A auto-refractor and via subjective refraction. RNFL thicknesses were then measured using the iVue-100 optical coherence tomography device. Axial lengths were measured with the Nidek US-500 A-scan ultrasound device. Data were analysed by descriptive statistics, *t*-tests, Pearson's correlation coefficients and regression analysis.

Results: The mean myopic spherical equivalent was significantly more negative amongst the Indian (-2.42 D ± 2.22 D) than amongst the black (-1.48 D ± 1.13 D) (p = 0.02) participants. The mean axial length was greater amongst the black (23.35 mm ± 0.74 mm) than amongst the Indian (23.18 mm ± 0.87 mm) participants but the difference was not significant. In the total sample (n = 80), the average global RNFL thickness ranged from 87 µm to 123 µm (105 µm ± 9 µm). Mean global RNFL thickness was slightly greater amongst black (108 µm ± 7 µm) than amongst Indian (102 µm ± 9 µm) (p = 0.00) participants. Mean global RNFL thickness was similar for male (106 µm ± 7 µm) and female (105 µm ± 10 µm) (p = 0.79) participants. A positive and significant association between myopic spherical equivalent and global RNFL thickness was found for the total sample (r = 0.36, p = 0.00) and for Indians (r = 0.33, p = 0.04) but not for the black (r = 0.25, p = 0.13) participants. There was a negative and significant correlation between axial length and global RNFL thickness amongst the Indian participants (r = -0.34, p = 0.03) but not amongst the total sample (r = -0.12, p = 0.30) or the black (r = 0.06, p = 0.73) participants.

Conclusion: The findings suggest that racial differences in RNFL thickness need to be considered in the clinical examination and screening for glaucoma and other optic nerve pathologies amongst black and Indian people. Additionally, the possible influences of refractive error and axial length should be considered when evaluating RNFL thickness.

Introduction

Glaucoma is the second leading cause of global blindness;[1] it is estimated that 60 million people are affected by this optic neuropathy.[2] The prevalence of glaucoma varies in different racial groups; primary open angle glaucoma is more prevalent amongst black African people, whilst angle closure glaucoma is more common amongst Asian people.[2,3] Glaucoma results in progressive damage to the retinal ganglion cells[4] and produces structural defects as well as thinning of the retinal nerve fibre layer (RNFL).[5,6] Anomalies of the RNFL precede visual field defects,[7,8] therefore assessment of the RNFL is important in the screening and monitoring of glaucoma.[9] There are various methods for imaging and clinically assessing the RNFL, including fundus photography, scanning laser polarimetry, confocal scanning laser ophthalmoscopy and optical coherence tomography.[6,9,10,11]

Optical coherence tomography (OCT) is an imaging technology, first described in 1991,[12] that is commonly used in the clinical imaging and quantitative assessment of ocular structures.[6] OCT works on a similar principle to ultrasonography except that light instead of sound waves are measured. In OCT, low-coherence interferometry is used to examine the reflected light waves and create a cross-sectional image (tomogram) of the tissue of interest. In retinal tomograms, the RNFL appears as a highly reflective layer owing to the perpendicular arrangement of fibres in relation to the direction of the OCT light beam.[6] This feature allows the borders of the RNFL to be automatically detected and its thickness measured using computer algorithms.[13] Several studies have reported OCT devices as reliable instruments for repeated measurements of RNFL thickness.[14,15,16,17]

RNFL thickness has been measured in various racial groups.[18,19,20,21,22,23,24,25,26] White subjects have been reported to have thinner RNFLs than those of black[11,18] or Asian.[19,27] However Alasil et al. found no difference in RNFL thickness between white and African-American subjects,[27] and Pilat et al. found no difference between white and Indian subjects.[28] Additionally, similar RNFL measurements have been reported[19,20,24,25,27] for male and female participants. Limited information is available on the ethnic variation for RNFL thickness in the South African population. Therefore, the present study was conducted to compare RNFL thickness in a healthy non-glaucomatous population of myopic black and Indian students.

Methodology

The study was approved by the Research and Higher Degrees Committee of the School of Health Sciences, University of KwaZulu-Natal, South Africa, and all ethical guidelines were adhered to during the study. The study location was the University of KwaZulu-Natal's Westville campus. Black and Indian populations were selected for the study as they represent the two major student groups at the study location. After obtaining ethical clearance, a pilot study was conducted on 10 participants to standardise the data collection procedure. A convenience sampling method was used to recruit the 80 South African black and Indian students included in the study. An equal number of men and women in both ethnic groups participated. All participants were aged between 18 and 24 years so as to minimise the effect of age on RNFL thickness measurements. Age is considered to have a significant effect on RNFL thickness measurements with many studies[11,27,29] reporting a decrease in RNFL thickness with increasing age. The reduction in RNFL thickness is presumably caused by the physiological loss of ganglion cell axons throughout life.[11]

Written informed consent was obtained from each participant after the nature of the study procedures had been explained. All participants underwent a complete ocular examination including a review of ocular and medical history, visual acuity testing, slit lamp examination, ophthalmoscopy and intraocular pressure measurement using the Nidek NT530P Tonopachy. This has been reported as a reliable instrument in comparison with the clinical gold-standard Goldmann applanation tonometer.[30] Both autorefraction (with the Nidek AR-310A) and subjective refraction were performed on all participants to determine their refractive errors. Autorefraction was performed to obtain the baseline refractive error that was subsequently refined using subjective refraction. The subjective refraction errors were used to determine the relevant spherical equivalents. Participants with any sign of ocular pathology, history of ocular surgery, ocular trauma or systemic disease, intraocular pressure ≥ 21 mmHg, or hyperopia or emmetropia were excluded. Corneal power and axial length were measured using the Oculus Keratograph and Nidek US-500 respectively.

All OCT scans were captured with the iVue-100 (Optovue, Inc.) OCT device. This spectral domain OCT device has a scanning rate of 26000 A-scan/s and axial resolution of 5 µm. The optic nerve head scanning protocol in the iVue-100 was used to determine the RNFL thickness. RNFL thickness is measured along a circle of 3.45 mm diameter centred on the optic disc. This scan determines the global RNFL thickness as well as the average RNFL thickness in the superior (46° – 135°), nasal (136° – 225°), inferior (226° – 315°) and temporal (316° – 45°) quadrants. Three consecutive readings for RNFL thickness were taken and averages computed. Repeat scans were taken if the signal strength of the scan was less than 40 or indicated as poor on the display, according to the manufacturer's recommendations.[31] The subjective refractions, OCT scans and axial length measurements were performed by one clinician each to ensure standardisation of test procedures and results. Data were captured and analysed using the Statistical Package for the Social Sciences (SPSS), version 21. The Shapiro-Wilk's test was used to evaluate the normality of the distributions of the data. Summary statistics such as means and standard deviations were used to detail the results. Independent sample *t*-tests were used to compare mean RNFL thickness in the two ethnic groups and between the two genders. Pearson's correlation coefficients were used to determine correlations between the study variables. Linear regression analysis was used to assess the relationship between myopic spherical equivalent and axial length on RNFL thickness. A probability (p) value < 0.05 was considered to be statistically significant.

Results

The right eyes only of the 80 participants were analysed. The ages of the 40 black participants ranged from 19 to 24 years (21.08 ± 1.90 years) and those of the 40 Indian participants ranged from 19 to 24 years (21.10 ± 1.41 years). Table 1 shows the demographic and ocular characteristics of the participants according to the two ethnic groups. The myopic spherical equivalent for black participants ranged from -0.25 D to -4.25 D (-1.48 D ± 1.13 D). The myopic spherical equivalent for Indian participants ranged from -0.25 D to -8.13 D (-2.42 D ± 2.22 D). The mean myopic spherical equivalent was significantly greater in Indian than in black participants ($p = 0.02$). The mean axial length for black participants was 23.35 mm ± 0.74 mm, with a range of 21.14 mm to 24.87 mm. The mean axial length for Indian participants was 23.18 mm ± 0.87 mm, with a range of 21.50 mm to 25.92 mm. The mean axial length was 0.2 mm longer in Indian than in black participants, although this difference was not statistically significant ($p = 0.33$). A significant correlation was found

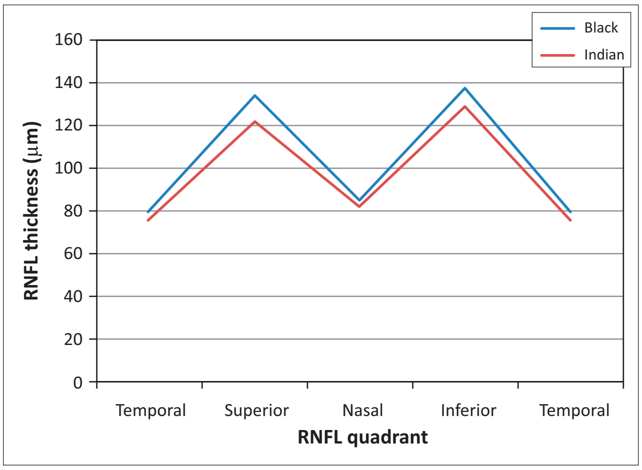
TABLE 1: Means and standard deviations for demographic and ocular characteristics of the black (n = 40) and Indian (n = 40) ethnic groups.

Demographic and ocular characteristics	Black (n = 40)	Indian (n = 40)
Age (years)	21.08±1.9	21.10±1.4
Spherical equivalent	-1.48±1.13	-2.42±2.22
Axial length (mm)	23.35±0.74	23.18±0.87
Horizontal corneal power (D)	42.08±1.83	43.05±1.53
Vertical corneal power (D)	43.29±1.62	43.96±1.35

TABLE 2: Retinal nerve fibre layer thickness (µm) variations in black and Indian ethnic groups indicated with means and standard deviations.

RNFL parameter	Black (n = 40)	Indian (n = 40)	p value†
Global	108±7	102±9	0.00‡
Superior	134±11	122±15	0.00‡
Inferior	138±14	129±17	0.01‡
Nasal	85±11	82±15	0.30
Temporal	79±24	76±9	0.46

RNFL, retinal nerve fibre layer.
†, t-test; ‡, statistically significant.



RNFL, retinal nerve fibre layer.

FIGURE 1: Retinal nerve fibre layer thickness for each quadrant in the black and Indian ethnic groups.

between the myopic spherical equivalent and axial length for Indian participants only (r = -0.54, p = 0.00) but not for black participants (r = -0.08, p = 0.62). The corneal powers were significantly greater amongst Indian than black participants for both the horizontal (p = 0.01) and vertical meridians (p = 0.05).

The average global RNFL of all the participants (n = 80) ranged from 87 µm to 123 µm (105 µm ± 9 µm). The means and standard deviations for global RNFL thicknesses and the RNFL thicknesses in each quadrant for the two ethnic groups are shown in Table 2. The mean global RNFL thickness was significantly greater in black than in Indian participants (p = 0.00). For each quadrant, the RNFL thickness was greater in black than Indian participants, but the difference was only significant in the superior (p = 0.00) and inferior (p = 0.01) quadrants. In both black and Indian participants, the inferior quadrant was the thickest, followed by the superior, nasal and temporal quadrants (Figure 1).

The global mean RNFL thickness was slightly higher in male (106 µm ± 7 µm) than in female participants (105 µm ± 10 µm) (p = 0.79). The RNFL thickness was slightly greater in female than in male participants in all quadrants except the inferior (Table 3) but these gender differences were not statistically significant (all p values >0.05).

Significant positive correlations were found between myopic spherical equivalent and RNFL thickness in the superior (r = 0.39, p = 0.00), inferior (r = 0.27, p = 0.02) and

TABLE 3: Means and standard deviations for retinal nerve fibre layer thickness variations in male and female participants.

RNFL parameter	Male (n = 40)	Female (n = 40)	p value†
Global	106±7	105±10	0.79
Superior	126±14	130±15	0.30
Inferior	135±15	132±18	0.51
Nasal	83±13	84±13	0.74
Temporal	76±8	80±24	0.39

RNFL, retinal nerve fibre layer.
Units are micrometres.
†, t-test.

TABLE 4: Pearson correlation analyses between retinal nerve fibre layer thickness and spherical equivalent and axial length in total sample.

RNFL quadrant	Spherical equivalent		Axial length	
	r value	p value	r value	p value
Superior	0.39	0.00*	-0.13	0.25
Inferior	0.27	0.02*	-0.15	0.18
Nasal	0.32	0.00*	-0.26	0.02*
Temporal	-0.15	0.18	-0.03	0.82

N = 80.
RNFL, retinal nerve fibre layer.
*, Statistically significant.

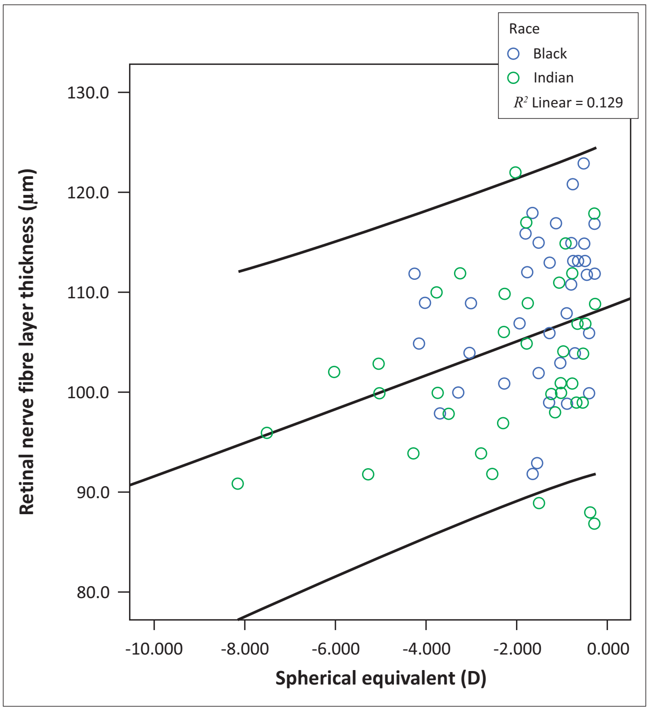
nasal (r = 0.32, p = 0.00) quadrants. Myopic spherical equivalent was inversely correlated with RNFL thickness in the temporal quadrant, but this correlation was weak and insignificant (r = -0.15, p = 0.18). Axial length was inversely correlated with RNFL thickness in all quadrants (Table 4) but the relationship was significant only in the nasal quadrant (r = -0.26, p = 0.02).

The association between myopic spherical equivalent and global RNFL thickness was positive but inconsistent as the association was significant in the total sample (r = 0.36, p = 0.00) and in Indian (r = 0.33, p = 0.04) but not in black participants (r = 0.25, p = 0.13). A scatter plot (Figure 2) shows the relationship between spherical equivalent and global RNFL for the two ethnic groups. From the regression line equation for the total sample, for every 1 D increase in spherical equivalent, global RNFL thickness will decrease by 1.71 µm.

Axial length was inversely and inconsistently associated with global RNFL thickness in the total sample (r = -0.12, p = 0.30) but, for Indian participants, an inverse and significant association was found (r = -0.34, p = 0.03). However, in black participants, axial length was not associated with global RNFL thickness (r = 0.06, p = 0.73). Figure 3 is a scatter plot showing the relationship between axial length and global RNFL for the two ethnic groups. From the regression line equation for the total sample, global RNFL thickness will decrease by 1.26 µm for every 1 mm increase in axial length.

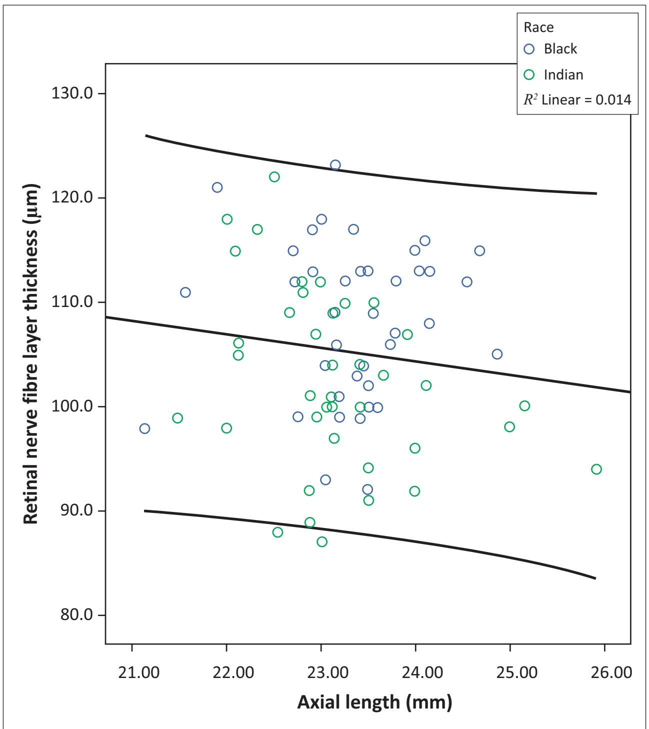
Discussion

In the present study, RNFL measurements were compared in a healthy non-glaucomatous group of myopic black and Indian students at the University of KwaZulu-Natal. Ethnic variations in RNFL thickness have been reported previously.[11,18,19,27] However, limited information is available



Note: The regression line shows global retinal nerve fibre layer = 109 + 1.71 (spherical equivalent).

FIGURE 2: Scatter plot showing the relationship of spherical equivalent and global retinal nerve fibre layer thickness (for the total sample) with 95% confidence interval of the regression line (R^2 = 0.13, r = 0.36, p = 0.00).



Note: The regression line represents global retinal nerve fibre layer = 135 − 1.26 (axial length).

FIGURE 3: Scatter plot showing the relationship of axial length and global retinal nerve fibre layer thickness (for the total sample) with 95% confidence interval of the regression line (R^2 = 0.01, r = -0.12, p = 0.30).

on the ethnic variation in RNFL thickness in the South African population. In the present study, the mean global RNFL thickness was slightly greater in black (108 µm) than in Indian participants (102 µm). This finding is in agreement with previous studies[11,18,19,27] which have shown that there are racial variations in RNFL thickness. The exact reason for these racial variations in RNFL thickness is unknown; however, earlier studies have suggested that differences in optic nerve head characteristics (disc area and rim area)[19,20,27] may account for some variations. Thinner RNFL thickness measurements are considered to be a predisposing factor for the development of glaucoma.[32,33] Therefore, the findings of this study suggest that the South African Indian population might be more susceptible to glaucoma than the South African black population. However, future studies comprising larger sample sizes, involving black and Indian participants of South African origin and consisting of glaucoma specific clinical tests (intraocular pressure measurements, ophthalmoscopy of the optic nerve head, gonioscopy and visual fields) are needed to validate such a conclusion.

The mean global RNFL of black participants (108 µm) in the present study was higher than the mean values reported in other black populations such as 95 µm to 101 µm in African-Americans,[19,27,34] 99 µm in African-Caribbeans,[34] and 94 µm in others of African descent.[20] This difference may be because the mean age of the study samples in the studies concerned[19,20,34] was older than that in the current study. Differences in study sample sizes and OCT device algorithms (software to detect retinal boundaries)[35,36] could also account for the variation observed. Some studies[19,27,34] included fewer black participants than the current study. However, this finding suggests that black South Africans may have thicker RNFLs than those of other black populations.

The mean global RNFL thickness of Indian participants (102 µm) in this study was comparable to four studies[35,36,37,38] in India involving Indian participants (101 µm – 105 µm). Furthermore, the mean RNFL thickness for Indian participants in the present study was similar to means reported in other Asian populations: 102 µm – 104 µm in Japanese[39,40] and 101 µm in Asians.[27] This finding suggests that Indian South Africans may have similar RNFL thicknesses to other Indian and Asian populations. In the present study, both black and Indian participants had thicker global RNFLs than the reported thickness values (range 80 µm – 98 µm) in studies[11,19,26,27,41,42] involving white participants. This finding is consistent with previous studies[11,18,19,27] where thinner RNFLs were reported in white participants than black and Asian participants.

For both the black and Indian participants, RNFL thickness was greatest in the inferior quadrant, followed by the superior, nasal and temporal. In the present study, variation of RNFL thickness in the different quadrants and following of the 'ISNT' rule described by Jonas et al.[43] is in agreement with previous studies.[18,19,20,22,25,36,38] Accordingly, findings in the present study also showed the characteristic 'double hump' pattern (Figure 1) of RNFL thickness seen in non-glaucomatous eyes with the inferior and superior quadrants being thicker than the nasal and temporal quadrants. However, this finding is in contrast to Ramakrishnan et al.[35]

where RNFL thickness was reported to be greatest in the superior quadrant. In Ramakrishnan et al.,[35] a Stratus OCT 3000 (Carl-Zeiss Ophthalmic Systems) was used to measure RNFL thickness. The Stratus OCT 3000 is a time-domain OCT device, which may account for the variation observed in the quadrant with the greatest thickness. No gender-related differences in global RNFL thickness were found ($p = 0.79$) in our study, which is in agreement with earlier studies.[20,24,27,35,36] Similar mean RNFL thicknesses measurements for each quadrant were recorded in male and female participants (all p values > 0.05).

Various studies[19,26,27,44,45] have reported significant correlations between global RNFL thickness and myopic spherical equivalent. However, Sony et al.[36] and Rao et al.[25] reported no significant association between these two clinical variables. In the present study, a positive association between global RNFL thickness and myopic spherical equivalent was found. However, this association was inconsequential as $r = 0.36$ ($p < 0.05$) in the total sample; and $r = 0.33$ ($p < 0.05$) in Indian and $r = 0.25$ ($p = 0.13$) in black participants. Apart from the temporal quadrant, RNFL thickness decreased with increasing myopic spherical equivalent in all quadrants (the relationship between myopic spherical equivalent and RNFL thickness in the various quadrants is shown in Table 4).

Inconsistent results have been reported for the correlation between global RNFL thickness and axial length, with most studies[19,26,33,44,45,46] reporting significant correlations, whilst other studies[25,36,47] report no correlation. In the present study, axial length was significantly and negatively associated with global RNFL thickness in Indian participants ($r = -0.34$, $p = 0.03$) but insignificantly associated in the total sample ($r = -0.12$, $p = 0.30$). For black participants, it was found that global RNFL thickness was not associated with increasing axial length ($r = 0.06$, $p = 0.73$). The relationship between axial length and RNFL thickness in the various quadrants is shown in Table 4. RNFL thickness decreased in all quadrants with increasing axial lengths. Leung et al.[32] suggests that such a reduction in RNFL thickness is because of elongation of the eye in myopia producing mechanical stretching and thinning of the retina. Furthermore, Tariq et al.[46] explained that in eyes with longer axial lengths, the area over which the retinal ganglion cells are spread is larger and may result in thinner RNFL measurements.

The strengths of the present study include the use of a high-resolution spectral domain OCT device, standardised examination techniques, a relatively homogenous sample and recording of several OCT measurements per eye. Possible limitations include the small sample size and the low range of myopic spherical equivalent considered. However, the purpose of the study was to provide baseline data on RNFL thickness measurements in blacks and Indians of South African origin. Therefore, it is recommended that future studies include larger samples, use a wider range of myopic spherical equivalent and be extended to other South African ethnic groups.

Conclusion

The present study compared the RNFL thickness in black and Indian myopic students at the University of KwaZulu-Natal. The findings suggest that mean global RNFL thickness is slightly greater in black South Africans than Indian South Africans. No clinically significant gender-related differences in global and quadrant specific RNFL thickness measurements were observed. Myopic spherical equivalent and axial length were associated with global RNFL. The findings suggest that the racial differences in RNFL thickness need to be considered in the diagnosis of glaucoma and other optic nerve pathologies. Additionally, the influence of myopic refractive error and axial length should be considered when evaluating RNFL thickness.

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Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

Authors' contributions

P.S. (University of KwaZulu-Natal) was the study leader. S.J. (University of KwaZulu-Natal) and N.R. (University of KwaZulu-Natal) provided feedback on the study design. C.M. (University of KwaZulu-Natal), B.Z.G. (University of KwaZulu-Natal), K.P. (University of KwaZulu-Natal), B.N.M. (University of KwaZulu-Natal), P.S. and S.K.M. (University of KwaZulu-Natal) performed the data collection. P.S., C.M., B.Z.G., K.P., B.N.M., S.K.M. and N.R. wrote the manuscript.

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