<table>
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<th><strong>Title</strong></th>
<th>Retinal Nerve Fiber Layer Thickness in Myopic, Emmetropic, and Hyperopic Children</th>
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The purpose of this study was to investigate the peripapillary retinal nerve fiber layer (RNFL) thickness in myopic, emmetropic, and hyperopic children using optical coherence tomography.

Two-hundred one right eyes of subjects aged 4 to 18 years were divided into 3 groups based on their postcycloplegic spherical equivalent: myopes (<−1.0 D), emmetropes (≥−1.0 to ≤+1.0 D), and hyperopes (>+1.0 D). The RNFL was correlated with age, spherical equivalent, and axial length. The RNFL was compared between the 3 groups before and after age adjustment.

The RNFL was thickest in the hyperopic group (107.2 ± 10.13 μm, n = 73), followed by the emmetropic group (102.5 ± 9.2 μm, n = 61), and then the myopic group (95.7 ± 10.3 μm) (all P < 0.0001). The myopic group (9.6 ± 3.9 years) was significantly older than the emmetropic (6.9 ± 2.7 years) and hyperopic (6.5 ± 1.9 years) groups (both P < 0.0001). When adjusted for age, myopes had a thinner RNFL than the other 2 groups (all P < 0.0001), but there was no RNFL thickness difference between the emmetropic and hyperopic groups (P > 0.05). A thinner RNFL was associated with an older age (r = −0.4, P < 0.0001), a more myopic spherical equivalent (r = 0.5, P < 0.0001), and a longer axial length (r = −0.4, P < 0.0001) on Pearson correlation analysis.

The apparently thicker RNFL in hyperopic and emmetropic children was attributed to their younger age as compared with their myopic counterparts. When adjusted for age, only myopia was associated with a thinner RNFL, with emmetropic and hyperopic children having equal RNFL thicknesses. Advancing age, a more myopic spherical equivalent, and a longer axial length were associated with a thinner RNFL in children.

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Spherical Equivalent and Axial Length

All subjects received cycloplegic refraction with 3 drops of Cyclopentolate hydrochloride 1% (Bausch & Lomb, Rochester, NY) administered 5 minutes apart to relieve all accommodative component. After at least 30 minutes, postcycloplegic
autorefractometry with a keratorefractometer (Topcon KR-8900; Topcon Europe Medical B.V., Capelle aan den IJssel, The Netherlands) was performed by an optometrist with at least 5 years of experience with pediatric assessment. The spherical equivalent was calculated in diopters. Axial length measurements in millimeters were obtained with the noncontact optical biometry (IOL Master; Carl Zeiss Meditec AG, Berlin, Germany).

**Peripapillary RNFL Thickness Measurement**

The protocol for RNFL measurement at our institution has been previously described in earlier publications by the authors\(^1\)–\(^3\) as “The Spectralis\(^\text{®}\) Spectral Domain OCT (Heidelberg Engineering, 1808 Aston Ave., Suite 103, Carlsbad, CA 92008, United States of America) was performed after cycloplegia, by a single, imaging technician who was masked to subjects’ clinical information. Scans were centred on the optic disc with a scanning diameter of 3.5 mm and 768 A-scans were obtained using the High Speed mode. To improve image quality, Automatic Real Time function was used to obtain multiple frames during scanning and to optimize images by noise reduction. Scans were repeated 3 times and assessed for signal strength and centration. Scans with signal strength quality ≤ 16 or poor centration were excluded. RNFL thickness was analysed with the RNFL Single Exam Report OU with fovea-to-disc technology. The RNFL thickness of each of the 4 quadrants and the global RNFL thickness were recorded in micrometers (\(\mu m\)).”\(^7\)

**Statistics**

Subjects were divided into 3 groups based on their post-cycloplegic spherical equivalent: myopic (\(< -1.0\text{D}\)), emmetropic (\(\geq -1.0\text{D} \leq +1.0\text{D}\)), and hyperopic (\(> +1.0\text{D}\)). Only the right eye of each subject was used for statistical analysis. Statistical significance was considered when \(P < 0.05\). Means were expressed with standard deviations.

The following were compared using one-way analysis of variance with Tukey multiple comparison test for the 3 groups:

- Age
- Spherical equivalent
- Axial length
- Global and quadrant RNFL thicknesses (before and after age adjustment)

Pearson correlation was used to analyze the association between the following parameters for the entire study population:

- RNFL (global and quadrant) thicknesses versus age
- RNFL (global and quadrant) thicknesses versus axial length
- RNFL (global and quadrant) thicknesses versus spherical equivalent
- Axial length versus age
- Axial length versus spherical equivalent

**RESULTS**

Of the 201 subjects eligible for the study, the mean age was 7.6 ± 3.3 years. There were 98 female and 103 male subjects; all were of Chinese ethnicity. There were 67 (33.1%) myopic eyes, 61 (30.1%) emmetropic eyes, and 73 (36.3%) hyperopic eyes. The mean RNFL thicknesses for the study population were interior (130.2 ± 21.1 \(\mu m\)), superior (125.9 ± 20.6 \(\mu m\)), nasal (63.6 ± 16.3 \(\mu m\)), temporal (87.4 ± 19.3 \(\mu m\)), and global (101.9 ± 11.0 \(\mu m\)).

The age distribution, spherical equivalent, axial length, RNFL, and age-adjusted RNFL of the myopic, emmetropic, and hyperopic groups were summarized in Table 1. The mean age in the myopic group was significantly older than the other 2 groups (all \(P < 0.0001\)). There was no significant age difference between the emmetropic and hyperopic group (\(P > 0.05\)). The mean spherical equivalents among the 3 groups were significantly different (all \(P < 0.0001\)). The axial length was the longest in the myopic group, followed by the emmetropic and hyperopic groups (all \(P < 0.0001\)). However, there was no significant difference in RNFL thickness between the emmetropic and hyperopic groups (\(P > 0.05\)) after age adjustment.

The correlations of RNFL thickness with age, spherical equivalent, and axial length were summarized in Table 2. There were significant correlations between the global RNFL with age (\(r = -0.4, P < 0.0001\)), spherical equivalent (\(r = -0.5, P < 0.0001\)), and axial length (\(r = -0.4, P < 0.0001\)) (Figures 1–3). There was a significant and negative correlation between the age and spherical equivalent (\(r = -0.3, \ldots\))

**TABLE 1. Differences in Age, Spherical Equivalent, Axial Length, and RNFL in Myopic, Emmetropic, and Hyperopic Children**

<table>
<thead>
<tr>
<th></th>
<th>Myopic Group (n = 67)</th>
<th>Emmetropic Group (n = 61)</th>
<th>Hyperopic Group (n = 73)</th>
<th>Statistical Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>9.6 ± 3.9</td>
<td>6.9 ± 2.7</td>
<td>6.5 ± 1.9</td>
<td>(P \leq 0.0001) for myopia vs emmetropia or hyperopia; (P &gt; 0.5) for emmetropia vs hyperopia</td>
</tr>
<tr>
<td>Spherical equivalent, D</td>
<td>–3.9 ± 2.2</td>
<td>+0.1 ± 0.5</td>
<td>+3.0 ± 1.6</td>
<td>(P &lt; 0.0001) between all groups</td>
</tr>
<tr>
<td>Axial length, mm</td>
<td>24.2 ± 1.3</td>
<td>22.8 ± 0.8</td>
<td>21.7 ± 0.8</td>
<td>(P &lt; 0.0001) between all groups</td>
</tr>
<tr>
<td>RNFL, (\mu m)</td>
<td>96.7 ± 10.3</td>
<td>102.5 ± 9.2</td>
<td>107.2 ± 10.1</td>
<td>(P &lt; 0.0001) between all groups</td>
</tr>
<tr>
<td>RNFL, (\mu m) after age adjustment (n = 35)</td>
<td>94.1 ± 12.2</td>
<td>102.5 ± 7.8</td>
<td>107.8 ± 11.6</td>
<td>(P &lt; 0.0001) for myopia vs emmetropia or hyperopia; (P &gt; 0.5) for emmetropia vs hyperopia</td>
</tr>
</tbody>
</table>

RNFL = retinal nerve fiber layer.
Myopic shift (study that an advancing age in childhood was associated with a 18 years. Likewise, Tong et al6 examined 316 Singaporean with age nor spherical equivalent in a population aged 7 to 30 years. The association between myopia and a thinner RNFL has been well documented in both children and adults, 14,16,17 although there are others who have reported differently. Chen et al18 did not find any association between the global RNFL thickness and refraction-related factors. On the contrary, hyperopia did not confer a thicker RNFL as compared with those with emmetropia. The apparent RNFL difference in the hyperopic group prior to age adjustment was probably a result of the younger age of subjects in this group rather than associations with their refractive status. Our findings were consistent with that of Tas et al,19 who reported similar RNFL thicknesses in those with high hyperopia (+9.50 D ≥ spherical equivalent ≥ +6.25 D) versus low hyperopia (+3.00 D ≥ spherical equivalent ≥ +0.50 D), but our result was in contrast to Zhu et al14 who reported an association between hyperopia and a thicker RNFL in a population of 12-year-olds in China.

The correlation of the temporal RNFL quadrant with age, spherical equivalent, and axial length was different to that of the other quadrants or the global RNFL thickness. There was no correlation between the temporal quadrant with age (r = 0.1, P = 0.06) despite significant correlations in the other quadrants and global RNFL (all P < 0.0004). There was a negative correlation of the temporal quadrant with spherical equivalent RNFL and Refractive Errors in Children

### DISCUSSION

The mean global RNFL thickness reported in our study (101.9 ± 11.0 μm) was consistent with that reported in the Anyang Childhood Eye Study (103.1 μm) and the Sydney Myopia Study (103.2 μm).14,15 We have reconfirmed in our study that an advancing age in childhood was associated with a myopic shift (r = −0.3, P < 0.0001) and axial length elongation (r = 0.5, P < 0.0001), and that a longer axial length resulted in a greater degree of myopia (r = −0.8, P < 0.0001).

The association between myopia and a thinner RNFL has been well documented in both children and adults, although there are others who have reported differently. Chen et al18 did not find any association between the global RNFL thickness and refraction-related factors. On the contrary, hyperopia did not confer a thicker RNFL as compared with those with emmetropia. The apparent RNFL difference in the hyperopic group prior to age adjustment was probably a result of the younger age of subjects in this group rather than associations with their refractive status. Our findings were consistent with that of Tas et al,19 who reported similar RNFL thicknesses in those with high hyperopia (+9.50 D ≥ spherical equivalent ≥ +6.25 D) versus low hyperopia (+3.00 D ≥ spherical equivalent ≥ +0.50 D), but our result was in contrast to Zhu et al14 who reported an association between hyperopia and a thicker RNFL in a population of 12-year-olds in China.

The correlation of the temporal RNFL quadrant with age, spherical equivalent, and axial length was different to that of the other quadrants or the global RNFL thickness. There was no correlation between the temporal quadrant with age (r = 0.1, P = 0.06) despite significant correlations in the other quadrants and global RNFL (all P < 0.0004). There was a negative correlation of the temporal quadrant with spherical equivalent

### TABLE 2. Correlations of RNFL (Global and Quadrant) Thicknesses With Age, Spherical Equivalent, and Axial Length

<table>
<thead>
<tr>
<th></th>
<th>Inferior</th>
<th>Superior</th>
<th>Nasal</th>
<th>Temporal</th>
<th>Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>r = −0.2</td>
<td>r = −0.2</td>
<td>r = −0.2</td>
<td>r = 0.1</td>
<td>r = −0.3</td>
</tr>
<tr>
<td>Spherical equivalent</td>
<td>r = 0.5</td>
<td>r = 0.4</td>
<td>r = 0.3</td>
<td>r = −0.2</td>
<td>r = 0.5</td>
</tr>
<tr>
<td>P ≥ 0.0004</td>
<td>P ≥ 0.0004</td>
<td>P ≥ 0.0004</td>
<td>P ≥ 0.0004</td>
<td>P ≥ 0.06*</td>
<td>P ≥ 0.0001</td>
</tr>
<tr>
<td>Axial length</td>
<td>r = −0.4</td>
<td>r = −0.4</td>
<td>r = −0.2</td>
<td>r = 0.2</td>
<td>r = −0.4</td>
</tr>
<tr>
<td>P ≤ 0.0001</td>
<td>P &lt; 0.0001</td>
<td>P &lt; 0.0001</td>
<td>P = 0.0004</td>
<td>P = 0.02</td>
<td>P &lt; 0.0001</td>
</tr>
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</table>

* Statistically insignificant.

P < 0.0001 and a positive correlation between age and axial length (r = 0.5, P < 0.0001). There was a significant and negative correlation between axial length and spherical equivalent (r = −0.8, P < 0.0001).

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**FIGURE 1.** Global RNFL thickness with spherical equivalent. RNFL = retinal nerve fiber layer.

**FIGURE 2.** Global RNFL thickness with age. RNFL = retinal nerve fiber layer.
FIGURE 3. Global RNFL thickness with axial length. RNFL = retinal nerve fiber layer.

\( r = -0.2, P = 0.009 \) and a positive correlation with axial length \( r = 0.2, P = 0.02 \) which was totally opposite to the results in the other quadrants and global RNFL thicknesses. Our findings were consistent with that of Xia et al\(^2\) and Chen et al\(^2\) who both reported a negative correlation between the temporal peripapillary RNFL thickness and spherical equivalent. Likewise, Kim et al\(^2\) reported a negative association between the temporal RNFL thickness and myopia. Furthermore, Leung et al\(^2\) and Tariq et al\(^2\) also reported a positive correlation between a longer axial length and thicker temporal RNFL, which is in line with our findings.

Our study had its limitations. There was no longitudinal follow-up to investigate the rate of RNFL thinning between the 3 groups. We excluded eyes with poor visual acuity but not for those with amblyopia because previous studies did not find any difference between the RNFL in the amblyopic versus the fellow normal eye.\(^2\) Likewise, we utilized all right eyes for the statistical analysis without consideration of eye dominance, as previous studies have found no difference in RNFL between the dominant versus nondominant eye.\(^2\) To the best of our knowledge, this is one of the few studies investigating the peripapillary RNFL thickness in children along the refractive error spectrum (myopia, emmetropia, and hyperopia), with adjustments in age, as well as including children as young as 4 years old, although the findings of our results may not be generalizable to all populations. The majority of studies in the literature have reported on the RNFL thickness in myopic or hyperopic children separately or included children 6 years or older.\(^2\) The peripapillary RNFL thickness varied among children with different refractive status, with hyperopes having the thickest and myopes having the thinnest RNFL. When adjusted for age, only myopic children having a significantly thinner RNFL. Thus, the apparent RNFL differences in emmetropic and hyperopic children seem to be attributed to differences in age rather than refractive status. Advancing age, a more myopic spherical equivalent, and a longer axial length were associated with a thinner RNFL in a population of Chinese children.

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REFERENCES


