Changes in falling risk depending on induced axis directions of astigmatism on static posture

SANG-YEOB KIM, MS, OPT1), BYEONG-YEON MOON, PhD, OPT1), HYUN GUG CHO, PhD, OPT1)*

1) Department of Optometry, Kangwon National University: Dogye, Samcheok 245-907, Republic of Korea

Abstract. [Purpose] To assess the changes in falling risk depending on the induced axis direction of astigmatism using cylindrical lenses in a static posture. [Subjects and Methods] Twenty subjects (10 males, 10 females; mean age, 23.4 ± 2.70 years) fully corrected by subjective refraction participated. To induce myopic simple astigmatism conditions, cylindrical lenses of +0.50, +1.00, +1.50, +2.00, +3.00, +4.00, and +5.00 D were used. The direction of astigmatic axes were induced under five conditions with increased cylindrical powers; 180°, 90°, and 45° on both eyes; 180°/90° right/left eye, and 45°/135° right/left eye. Changes in the fall risk index were analyzed using the TETRAX biofeedback system. Measurements were performed for 32 seconds for each condition. [Results] The fall risk index increased significantly from C+4.00 D in 180°/90° right/left eye, C+3.00 D in 45°/135° right/left eye, and C+3.00 D in 45° on both eyes versus corrected emmetropia. Among the five axis conditions with the same cylindrical power lenses, the increase in the fall risk index was highest at 45° in both eyes. [Conclusion] Uncorrected oblique astigmatism may increase falling risk compared to with-the-rule and against-the-rule astigmatism. Clinical specialists should consider appropriate correction of astigmatism for preventing falls, especially for uncorrected oblique astigmatism.

Key words: Fall risk index, Astigmatism, Axis directions

INTRODUCTION

Vision plays an important role in postural stability for body balance1, 2), safe negotiation of steps and stairs3), and the avoidance of obstacles in the path of travel4). The most common causes of visual impairment in older adults are cataract and refractive error5, 6); the resultant poor vision reduces postural stability and significantly increases the risk of falls in both older and young people1, 7, 8). Jack et al.9) reported a particularly high prevalence (76%) of visual impairment in patients admitted to a hospital clinic owing to falls and that 79% of these visual impairments were reversible, mainly by updating glasses (40%) or cataract surgery (37%). These finding indicate appropriate surgical or optical correction would help prevent falling risk. However, most recent studies associated with falls have focused on physical therapy for elderly patients10–12).

Regarding the effects on body balance associated with retinal defocus, Edwards13) and Paulus et al.14) reported body instability increases approximately 25 to 28% with the addition of a +4 to +6 D spherical lens. Furthermore, Anand et al.15, 16) reported that the changes in standing stability with added lenses of +1, +2, +4, and +8 D in younger and older subjects are more affected under complicated conditions in which normal information from the vestibular and somatosensory systems is disrupted.

However, a limitation of those studies is that subjects only had myopic defocus. Accordingly, we previously analyzed the changes of general stability and fall risk index (FI) under the conditions of various types of ametropia and found that uncorrected hyperopia may cause subjects to have a higher risk of falling than uncorrected myopia17). Therefore, the present study investigated the effect of the axis direction of uncorrected astigmatism on falling risk.

SUBJECTS AND METHODS

Twenty subjects (10 males, 10 females) with a mean age of 23.4 ± 2.70 years with myopic astigmatism error participated in this study. All subjects were healthy and had no neurological, otoneurological, or ophthalmological disease. They were not taking any medications that might interfere with balance control. The astigmatism of the subjects is ranged from −0.25 D to −2.50 D. Regarding the astigmatism type, 23 eyes were with-the-rule (i.e., corrective axes within 180 ± 15°), 15 eyes against-the-rule (i.e., within 90 ± 15°), and 2 eyes oblique (i.e., 15 −75° or 105 −165°). All subjects had visual acuity better than 1.0 in each eye and depth perception of 50 seconds of arc or better on the Titmus fly stereocuity test. All subjects understood the purpose of this study and provided informed consent to participate. This study was conducted in accordance with the ethical
Table 1. Changes in the fall risk index with respect to the induced axis directions of astigmatism with increase of (+) cylindrical lens power

<table>
<thead>
<tr>
<th>Cylindrical lens power (+D)</th>
<th>Axis directions of cylindrical lenses</th>
<th>0.00</th>
<th>0.50</th>
<th>1.00</th>
<th>1.50</th>
<th>2.00</th>
<th>3.00</th>
<th>4.00</th>
<th>5.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>180° on both eyes</td>
<td>2.00 ± 3.31</td>
<td>2.60 ± 3.62</td>
<td>3.80 ± 4.49</td>
<td>3.50 ± 4.35</td>
<td>4.10 ± 4.75</td>
<td>4.60 ± 4.99</td>
<td>4.50 ± 5.58</td>
<td>4.50 ± 5.88</td>
<td>4.50 ± 5.88</td>
</tr>
<tr>
<td>90° on both eyes</td>
<td>2.00 ± 3.31</td>
<td>3.00 ± 3.64</td>
<td>4.40 ± 3.98</td>
<td>4.10 ± 5.60</td>
<td>5.40 ± 6.87</td>
<td>4.60 ± 5.95</td>
<td>4.80 ± 5.43</td>
<td>4.80 ± 5.32</td>
<td>4.80 ± 5.32</td>
</tr>
<tr>
<td>180° − right eye/90° − left eye</td>
<td>2.00 ± 3.31</td>
<td>3.20 ± 3.27</td>
<td>4.10 ± 4.52</td>
<td>4.10 ± 4.42</td>
<td>5.00 ± 4.79</td>
<td>5.60 ± 5.46</td>
<td>6.00 ± 5.36</td>
<td>6.10 ± 4.61</td>
<td>5.50 ± 4.63</td>
</tr>
<tr>
<td>90° − left eye</td>
<td>2.00 ± 3.31</td>
<td>3.30 ± 4.12</td>
<td>4.70 ± 4.69</td>
<td>5.10 ± 4.61</td>
<td>6.00 ± 5.43</td>
<td>6.60 ± 5.35</td>
<td>7.00 ± 6.87</td>
<td>7.00 ± 8.39</td>
<td>9.00 ± 6.70</td>
</tr>
<tr>
<td>135° − left eye</td>
<td>2.00 ± 3.31</td>
<td>3.80 ± 4.54</td>
<td>4.50 ± 4.30</td>
<td>5.10 ± 4.52</td>
<td>6.60 ± 5.43</td>
<td>6.80 ± 5.36</td>
<td>7.70 ± 8.39</td>
<td>7.70 ± 8.39</td>
<td>9.50 ± 6.70</td>
</tr>
</tbody>
</table>

Significant differences between subgroups by Duncan’s one way ANOVA (*p < 0.05).
Data are expressed as mean ± SD.
Data in parentheses indicate percentage increase in the FI compared to that with corrected emmetropia (0.00 D).

To assess change in the FI, we used the TETRAX biofeedback system (Tetrax Portable Multiple System, Tetrax Ltd., Rannmat Gan, Israel) which measures the postural sway on 4 force plates, 1 each for the toes and heels of each foot. The FI indicates the likelihood that the patient will fall, with higher values indicating a greater chance of falling.

Before the FI was assessed, the examiner corrected all subjects to emmetropia by subjective refraction with a phoropter (Ultramatic RX Master, Reichert, Depew, NY, USA) and a 5-m visual chart. The examiner subsequently asked the subject to wear trial frames with full correction along 2 meridians, which can perturb visual recognition. Astigmatism produces different amounts of magnification along 2 meridians; these lenses have zero power along their axis directions of cylindrical lenses. In astigmatism induced by 180° and 90° on both eyes, there was no significant change of the FI with the increasing cylindrical lens power. However, the FI increased significantly (p < 0.05) from C+4.00 D under 180° on the right eye/90° on the left eye, from C+3.00 D in 45° on the right eye/135° on the left eye, and from C+3.00 D in 45° on both eyes conditions compared to that under corrected emmetropia. The FI increased most in the 45° on both eyes condition, followed by 45° on the right eye/135° on the left eye, 180° on the right eye/90° on the left eye, 90° on both eye and 180° on both eyes.

DISCUSSION

Astigmatism is a common refractive error that can be corrected by cylindrical or toric lenses of different powers in different meridians; these lenses have zero power along their axis direction, so that the power is perpendicular to the axis. Astigmatism produces different amounts of magnification along 2 meridians, which can perturb visual recognition.

The FI increased significantly from C+4.00 D in the condition of 180° on the right eye/90° on the left eye, C+3.00 D in 45° on the right eye/135° on the left eye, C+3.00 D in 45° on both eyes compared to that under corrected emmetropia. Johnson et al. investigated the effect of induced astigmatism on locomotor stepping patterns in subjects blurred with ±3.00 D cylinders at axes of 180°, 90°, 135° and 45°; they reported obliquely induced astigmatism causes more gait changes than vertically and horizontally induced astigmatism despite similar visual acuity levels with the addition of all cylindrical lenses. Moreover, Chapman et al. investigated the effects of ocular magnification on adaptive gait with size lenses producing ocular magnification of ±1%, ±2%, ±3%, and ±5%; they suggest the observed adaptive gait changes are driven by magnification changes rather than optical blurring. Although the present experiment was performed under the condition of an upright position, similar results were obtained. Furthermore, the percentage increases of the FI indicate that although the uncorrected cylindrical astigmatism induced by uncorrected axis directions are shown in
powers were equal, parallel oblique astigmatism induced the greatest potential risk of falling.

As mentioned above, astigmatism induces different amounts of magnification along 2 meridians. In particular, when cylindrical lenses are placed at oblique axes, magnification is provided along an oblique meridian. In the case of astigmatism induced by 45° on both eyes, a visual recognition change that would cause magnification sloped down towards the left (from the subject’s perspective) will occur. Subjects may be unaccustomed to such changes, because the real world is mostly horizontal-vertical structures. In addition, the behavior refractive error of almost all subjects in the present study was not oblique astigmatism.

The magnification by spectacle lenses affects the change of vestibulo-ocular reflex (VOR) gain, which links the vestibular system with the extra-ocular muscles. The VOR gain increased by near-viewing distance on new spectacles must be adjusted rapidly to maintain accurate VOR behavior. However, patients with large changes in prescription may experience disorientation symptoms such as slight dizziness and vertigo; these symptoms lead to visual disturbances and distortion of images, and dizziness may result in loss of balance and falls. As a result, we suggest that with large increases in VOR, the additional slanting and magnifying cognitive change due to uncorrected oblique astigmatism can decrease stability in body balance and thus increase the risk of falling. Although a limitation of the present study is the range of the subjects’ age, the aforementioned risk of falling should be considered greater in older patients, because the declines in the VOR with age are associated with body balance problems.

In conclusion, uncorrected oblique astigmatism has a greater effect on the F1 than uncorrected with-the-rule and against-the-rule astigmatism. Therefore, clinicians should counsel patients about the effects of astigmatism on falling risk and consider appropriate correction of astigmatism for preventing falls, especially uncorrected parallel oblique astigmatism. In addition, if necessary, partial correction should be considered to reduce adaptation problems due to increased magnification caused by updating prescription in older patient.

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