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

Sang-Yeob Kim, MS, OPT[1)], Byeong-Yeon Moon, PhD, OPT[1)], Hyun Gug Cho, PhD, OPT[1)*]

[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

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INTRODUCTION

Vision plays an important role in postural stability for body balance[1, 2)], safe negotiation of steps and stairs[3)], and the avoidance of obstacles in the path of travel[4)]. The most common causes of visual impairment in older adults are cataract and refractive error[5, 6)]; the resultant poor vision reduces postural stability and significantly increases the risk of falls in both older and young people[1, 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 patients[10–12)].

Regarding the effects on body balance associated with retinal defocus, Edwards[13)] 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 myopia[17)]. 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 interfer 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 stereoacuity test. All subjects understood the purpose of this study and provided informed consent to participate. This study was conducted in accordance with the ethical

*Corresponding author. Hyun Gug Cho (E-mail: hyung@kangwon.ac.kr)

Table 1. Changes in the fall risk index with respect to the induced axis directions of astigmatism with increase of (+) cylindrical lens power

Cylindrical lens power (+D)	Axis directions of cylindrical lenses				
	180° on both eyes	90° on both eyes	180° − right eye/ 90° − left eye	45° − right eye/ 135° − left eye	45° on both eyes
0.00	2.00 ± 3.31	2.00 ± 3.31	2.00 ± 3.31[a]	2.00 ± 3.31[a]	2.00 ± 3.31[a]
0.50	2.60 ± 3.62 (30%)	3.00 ± 3.64 (50%)	3.20 ± 3.27[ab] (60%)	3.30 ± 4.12[ab] (65%)	3.80 ± 4.54[a] (90%)
1.00	3.80 ± 4.49 (90%)	4.40 ± 3.98 (120%)	4.10 ± 4.52[abc] (105%)	4.70 ± 4.69[abc] (135%)	4.50 ± 4.30[a] (125%)
1.50	3.00 ± 2.94 (50%)	4.10 ± 3.97 (105%)	4.30 ± 4.46[abc] (115%)	5.10 ± 4.52[abc] (155%)	5.10 ± 5.05[ab] (155%)
2.00	3.50 ± 4.35 (75%)	4.10 ± 5.60 (105%)	4.10 ± 4.42[abc] (105%)	5.10 ± 4.61[abc] (155%)	6.00 ± 7.84[ab] (200%)
3.00	4.10 ± 4.75 (105%)	5.40 ± 6.87 (170%)	5.00 ± 4.79[abc] (150%)	5.60 ± 4.43[bc] (180%)	6.80 ± 8.35[bc] (240%)
4.00	4.60 ± 4.99 (130%)	4.60 ± 5.95 (130%)	6.40 ± 5.86[bc] (220%)	6.60 ± 5.35[c] (230%)	7.70 ± 8.39[bc] (285%)
5.00	4.50 ± 5.58 (125%)	4.80 ± 5.41 (140%)	6.70 ± 6.30[c] (235%)	6.80 ± 4.92[c] (240%)	9.50 ± 6.70[c] (375%)
p-value	0.502	0.483	0.039*	0.018*	0.013*

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).

principles of the Declaration of Helsinki.

To assess change in the FI, we used the TETRAX biofeedback system (Tetrax Portable Multiple System, Tetrax Ltd., Ranmat 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[18)] 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 and stand upright on the force plate. To induce astigmatism (i.e., binocular simple myopic), cylindrical trial lenses of +0.50, +1.00, +1.50, +2.00, +3.00, +4.00, and +5.00 D were used, and the various axis directions of the cylindrical lenses were placed on the fully corrected trial frames. The axis directions of cylindrical lenses were aligned as under five trial conditions: 180°, 90°, 45° on both eyes; 180° on the right eye/90° on the left eye; and 45° on the right eye/135° on the left eye.

The FI was assessed for 32 seconds for each condition. A 1-minute rest was allowed while the power of (+) the cylindrical lens was changed, and a 10-minute rest was allowed when the corrective axes of astigmatism were changed. The FI values were recorded as deviations from the value under the emmetropic condition. Each subject was instructed to keep looking at a fixed target at 30 m away during measurements.

For comparing the values of FI under five conditions of axis directions with increased cylindrical powers, the data were analyzed by one-way analysis of variance (ANOVA) using SPSS for Windows (SPSS Inc., Chicago, IL, USA), a value of $p \leq 0.05$ was considered significant.

RESULTS

The changes of the FI under each condition of astigmatism induced by uncorrected axis directions are shown in Table 1. 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[19–21)] 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[22)], 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, from C+3.00 D in 45° on both eyes compared to that under corrected emmetropia. Johnson et al.[23)] 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.[24)] 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. Furthemore, the percentage increases of the FI indicate that although the uncorrected cylindrical 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[23]. 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[25]. The VOR gain increased by near-viewing distance[26] or new spectacles must be adjusted rapidly to maintain accurate VOR behavior[27]. However, patients with large changes in prescription may experience disorientation symptoms such as slight dizziness and vertigo[28]; these symptoms lead to visual disturbances and distortion of images, and dizziness may result in loss of balance and falls[29]. 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[30].

In conclusion, uncorrected oblique astigmatism has a greater effect on the FI 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.

REFERENCES

1) Lord SR: Visual risk factors for falls in older people. Age Ageing, 2006, 35: ii42–ii45. [Medline]
2) Schwartz S, Segal O, Barkana Y, et al.: The effect of cataract surgery on postural control. Invest Ophthalmol Vis Sci, 2005, 46: 920–924. [Medline] [CrossRef]
3) Startzell JK, Owens DA, Mulfinger LM, et al.: Stair negotiation in older people: a review. J Am Geriatr Soc, 2000, 48: 567–580. [Medline]
4) Campbell AJ, Robertson MC, La Grow SJ, et al.: Randomised controlled trial of prevention of falls in people aged ≥75 with severe visual impairment: the VIP trial. BMJ, 2005, 331: 817.
5) van der Pols JC, Thompson JR, Bates CJ, et al.: Is the frequency of having an eye test associated with socioeconomic factors? A national cross sectional study in British elderly. J Epidemiol Community Health, 1999, 53: 737–738. [Medline] [CrossRef]
6) Wormald RP, Wright LA, Courtney P, et al.: Visual problems in the elderly population and implications for services. BMJ, 1992, 304: 1226–1229. [Medline] [CrossRef]
7) Rubenstein LZ, Josephson KR: The epidemiology of falls and syncope. Clin Geriatr Med, 2002, 18: 141–158. [Medline] [CrossRef]
8) Abdelhafiz AH, Austin CA: Visual factors should be assessed in older people presenting with falls or hip fracture. Age Ageing, 2003, 32: 26–30. [Medline] [CrossRef]
9) Jack CI, Smith T, Neoh C, et al.: Prevalence of low vision in elderly patients admitted to an acute geriatric unit in Liverpool: elderly people who fall are more likely to have low vision. Gerontology, 1995, 41: 280–285. [Medline] [CrossRef]
10) Sugihara T, Mishima S, Tanaka M, et al.: physical ability estimation and falling in the elderly. J Phys Ther Sci, 2006, 18: 137–141. [CrossRef]
11) Kang KY: Effects of visual biofeedback training for fall prevention in the elderly. J Phys Ther Sci, 2013, 25: 1393–1395. [Medline] [CrossRef]
12) Choi JH, Kim NJ: The effects of balance training and ankle training on the gait of elderly people who have fallen. J Phys Ther Sci, 2015, 27: 139–142. [Medline] [CrossRef]
13) Edwards AS: Body sway and vision. J Exp Psychol, 1946, 36: 526–535. [Medline] [CrossRef]
14) Paulus WM, Straube A, Brandt T: Visual stabilization of posture. Physiological stimulus characteristics and clinical aspects. Brain, 1984, 107: 1143–1163. [Medline] [CrossRef]
15) Anand V, Buckley J, Scally A, et al.: The effect of refractive blur on postural stability. Ophthalmic Physiol Opt, 2002, 22: 528–534. [Medline] [CrossRef]
16) Anand V, Buckley JG, Scally A, et al.: Postural stability in the elderly during sensory perturbations and dual tasking: the influence of refractive blur. Invest Ophthalmol Vis Sci, 2003, 44: 2885–2891. [Medline] [CrossRef]
17) Kim SY, Moon BY, Cho HG: Body balance under ametropia conditions induced by spherical lenses in an upright position. J Phys Ther Sci, 2015, 27: 615–618. [CrossRef]
18) Carlson NB, Kurtz D: Clinical procedures for ocular examination, 3rd ed. New York: McGraw-Hill, 2003, pp 90–117.
19) Buckhurst PJ, Wolffsohn JS, Davies LN, et al.: Surgical correction of astigmatism during cataract surgery. Clin Exp Optom, 2010, 93: 409–418. [Medline] [CrossRef]
20) Read SA, Collins MJ, Carney LG: A review of astigmatism and its possible genesis. Clin Exp Optom, 2007, 90: 5–19. [Medline] [CrossRef]
21) Pesudovs K, Elliott DB: Refractive error changes in cortical, nuclear, and posterior subcapsular cataracts. Br J Ophthalmol, 2003, 87: 964–967. [Medline] [CrossRef]
22) Adams WJ, Banks MS, van Ee R: Adaptation to three-dimensional distortions in human vision. Nat Neurosci, 2001, 4: 1063–1064. [Medline] [CrossRef]
23) Johnson L, Supuk E, Buckley JG, et al.: Effects of induced astigmatism on foot placement strategies when stepping onto a raised surface. PLoS ONE, 2013, 8: e63351. [Medline] [CrossRef]
24) Chapman GJ, Scally AJ, Elliott DB: Adaptive gait changes in older people due to lens magnification. Ophthalmic Physiol Opt, 2011, 31: 311–317. [Medline] [CrossRef]
25) Demer JL, Porter FI, Goldberg J, et al.: Adaptation to telescopic spectacles: vestibulo-ocular reflex plasticity. Invest Ophthalmol Vis Sci, 1989, 30: 159–170. [Medline]
26) Hine T, Thorn F: Compensatory eye movements during active head rotation for near targets: effects of imagination, rapid head oscillation and vergence. Vision Res, 1987, 27: 1639–1657. [Medline] [CrossRef]
27) Leigh R, Zee OS: The Neurology of Eye Movements, 2nd ed. Philadelphia: FA Davis, 1991, pp 3–79.
28) Benjamin WJ: Borish's Clinical Refraction, 2nd ed. St. Louis: Butterworth-Heinemann: Elsevier, 2006, pp 160–161.
29) Huijbregts P, Vidal P: Dizziness in orthopaedic physical therapy practice: classification and pathophysiology. J Manual Manip Ther, 2004, 12: 199–214. [CrossRef]
30) Kerber KA, Ishiyama GP, Baloh RW: A longitudinal study of oculomotor function in normal older people. Neurobiol Aging, 2006, 27: 1346–1353. [Medline] [CrossRef]