

Effect of Yoked Prism on Postural Control Ability

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ABSTRACT

This study aimed to investigate the effect of spatial perception change that occurs when wearing a yoked prism on postural control ability.

Twenty-seven myopic patients (13 males, 14 females) with an average age of 22.74 ± 1.61 years were enrolled in this study. Under the conditions of adding a horizontal-yoked prism, vertical-yoked prism, and diagonal-yoked prism to the front of the subject's glasses, stability index, fall risk index, and synchronization index were measured using the TETRAX biofeedback system. These were compared to baseline data obtained before the subjects wear each yoked prism.

Among the induced yoked prism effects, the general stability index significantly increased in the conditions where vertical-yoked prism and diagonal-yoked prism were worn, compared to before the prisms were worn ($p < 0.05$). In particular, the diagonal-yoked prism caused an increase in the fall risk index compared to the baseline data ($p < 0.05$). Results of the synchronization index analysis showed there was no significant change in the horizontal-yoked prism and vertical-yoked prism wearing conditions, but when the diagonal-yoked prism was worn, AB, CD, and BD among the six synchronization indices showed a marked decrease compared to before the prisms were worn ($p < 0.05$). A temporary visual field shift due to the yoked prism may cause a spatial perception change and increase overall body sway. In particular, if the field of view is changed to the upward or diagonal direction, postural instability may increase, thereby causing risk of a fall. Thus, when deciding to prescribe a yoked prism in the clinical field of optometry, sufficient observation on postural adaptation should be made.

Keywords

Yoked prism; Postural stability; Stability index; Fall risk index; Synchronization index

Introduction

Postural control is defined as the ability to maintain the body's center of gravity.^[1] Among the sensory organs responsible for postural control, the visual system primarily provides information about the external environment and the body position to the environment continuously. This whole process is carried out in interaction with other sensory organs and play a very important role in maintaining a stable body balance.^[2] Visual acuity, depth perception, and contrast sensitivity are major visual functions for accurate object recognition and spatial recognition. It is known that if these functions are poor, they negatively affect the body balance ability.^[3,4] Recently, our research team^[5] conducted a study to analyze whether optical correction for residual refractive error had a positive effect on postural control. Results confirmed that the postural stability of the subject was improved immediately after wearing the new corrective glasses. Based on these results, we have emphasized that optimal refractive error correction is an optical intervention strategy that can improve various visual functions, enhance overall body balance ability, and reduce risk of falls.

If the gaze of both eyes turns to the same direction even while wearing glasses for refractive error correction, the yoked prism effect occurs as the visual axis deviates from the optical center of the spectacle lens. In the clinical field of optometry, the base of the prism is placed in the same direction in both eyes of the subject using this yoked prism effect. The entire field of view is moved in the right angle^[6] to apply it to patients who

cannot move their eyes smoothly due to anomalous head posture correction by strabismus and nystagmus, vision training, or physical disabilities^[7,8]. However, the yoked prism may cause dizziness and imbalance in sensory integration depending on the degree of changes in sensory vision, motor vision, and egocentric spatial perception of the individual who wears the glasses.^[9] Thus, it is expected that even a temporary change in body balance ability will result. Analyzing the changes in the evaluation factors of postural control attributed to the effect of these yoked prisms can be a useful clinical reference in predicting the appropriate adaptation of eyeglass-wearers in the field of optometry. However, studies related to yoked prism were limited to surveys and evaluation of changes in the subjective visual sense such as dizziness of the wearer according to the induced yoked prism effect.^[10] Until recently, studies dealing with the effects of these yoked prisms on postural stability have been very few.

Therefore, this study attempted to analyze the effect on static postural control ability after experimentally inducing a representative basal direction condition that can prescribe yoked prism in 27 healthy adult myopic patients.

Subjects and Methods

1. Subjects

This study was conducted on 27 myopic patients (13 males and 14 females) with an average age of 22.74 ± 1.61 years. Through the clinical interview, it was confirmed that the subjects had no muscle disease, systemic disease or eye disease, which are related to body balance or falls, and no related medications taken. In addition, subjects with non-strabismic binocular dysfunction, accommodative function abnormality, abnormal eye movements, or refractive error correction values in the left and right eyes differing by more than 1D were excluded from this study through the visual function test. The average binocular spherical equivalent refractive power of the subjects was $S-3.73 \pm 2.45$ D, with an average of $1.52 \pm 2.90 \Delta$ exophoria in the distance horizontal phoria and $0.22 \pm 1.34 \Delta$ in the distance vertical phoria. All the test subjects understood the purpose of this study and consented to participate therein. The study was conducted in conformity with the ethical principles of the Declaration of Helsinki.

2. Measuring Equipment

To evaluate the changes in body balance that occur after wearing the yoked prism, the TETRAX® interactive postural balance system (Tetrax Postable Multiple System, Tetrax Ltd, Ranmat Gan, Israel) was used (Fig. 1). The TETRAX system consists of four force-plates sensing devices divided into A (left heel), B (left toe), C (right heel), and D (right toe) (Fig. 2A). The four force-plates sensing devices comprehensively analyze the shaking area, length, speed, and center of gravity movement pattern in a static state for 32 seconds. This information is numerically displayed to evaluate various body balance abilities^[11]



Figure 1. TETRAX biofeedback device used in this study

3. Measurement Factors

In this study, the following analyses were performed using the TETRAX device.^[11-13]

(1) Stability Index

It is an index indicating stability by measuring the overall sway of the body. The higher the value, the more unstable the body balance becomes.

(2) Fall Risk Index

The fall risk index refers to the risk of falls that can injure the human body, including slipping and falling or falling from a high place. This index is the sum of the standard deviations of stability index, vestibular organ measurement index, somatosensory measurement index, and synchronization. It is classified into mild risk (0 to 35), moderate risk (36 to 57), and high risk (58 to 100).

(3) Synchronization Index

Synchronization index analysis shows the waveform correlation of vibrations measured in two ground reaction forces selected among the four ground reaction force devices. In each force-plates device, the interaction between each area is analyzed by measuring the change in weight distribution on the entire left foot and the entire right foot, and on the toe and heel of each foot. In the force-plates area composed of A, B, C, and D, pairwise classification was performed into A and B, C and D, A and C, B and D, A and D, and B and C. Subsequently, synchronization ability was analyzed (Fig. 2B). For A and B, C and D, A and D, and B and C, as they have a (-) value and for A and C and B and D, as they have a (+) value, synchronization ability is interpreted as excellent. When the measurement range of these values is -1000 to 1000, the absolute value is 700 or more if the body balance ability is normal, and an absolute value of below 700 means that the synchronization ability between each foot area is reduced.

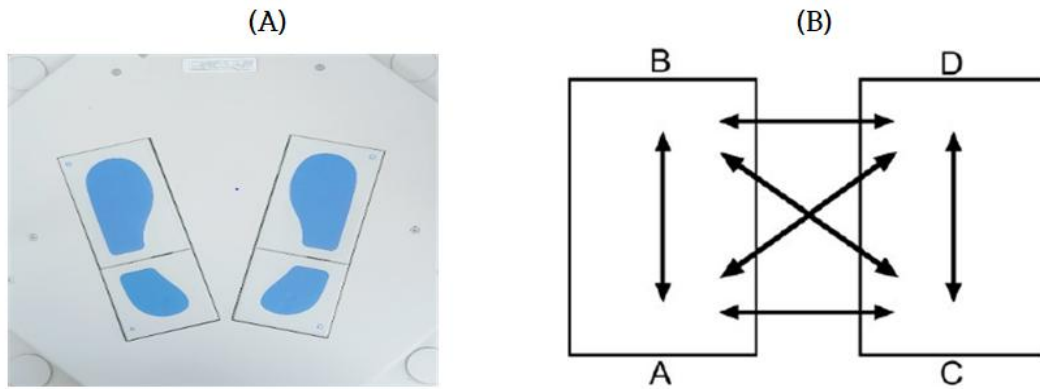


Figure 2. Four plates on TETRAX biofeedback device (A) and Schematic diagram of six synchronization (B).

4. Measurement Method

One skilled examiner performed a subjective refraction test to make the corrective glasses for subjects using a manual phoropter (CV-3000, Topcon, Japan) and LCD visual acuity chart (LUCID'LC, Everview, Korea). To determine the exact PD and Oh of the subjects, a digital PD imaging device (Eye M, EYEME Optic, Korea) was used. Fully corrected glasses were produced and provided to each subject. In order to adapt to the new glasses, the subjects were asked to wear glasses all day for two days prior to the experiment, and postural evaluation measurements were performed thereafter. To measure the postural evaluation factors, the subjects were asked to stand on the ground reaction force sensing device of the TETRAX measuring device with bare feet. Both feet were symmetrically aligned left and right on the ground reaction force sensing device marked with A (heel of left foot), B (toe of left foot), C (heel of right foot), and D (toe of right foot), and a comfortable anatomical position was taken. After 10 seconds of preparation time in the static posture, measurement was performed for 32 seconds according to the manual of the measuring equipment. In order to exclude the accommodative reaction of the eyes as much as possible, the gaze target was a gaze point with a 0.05 decimal visual acuity fixed at 12 m in front.

In this study, the experimental visual field movement conditions by yoked prism were selected as the following three conditions.

- 1) Horizontal-yoked prism condition (R-BI & L-BO prism are worn; the entire field of view is shifted to the right)
- 2) Vertical-yoked prism condition (BD prism is worn in each eye; the entire field of view is shifted upward)
- 3) Diagonal-yoked prism condition (Base 135° prism is worn in each eye; the entire field of view is shifted to the left-bottom)

In order to induce the effect of yoked prism in three different directions as above, the prism was inserted into a trial lens clip (HOYA lens, Japan) that can be used over the glasses provided to the subject. To control the degree of visual field shift for each condition, 2 Δ and 4 Δ prisms were used for each eye. The general stability index and fall risk index were measured in each visual field shift condition induced by the yoked prism, and then compared with the values measured in the condition where the yoked prism was not inserted. By analyzing the synchronization index, this study tried to

investigate the cause of the change in the stability index and fall risk index attributed to the effect of the yoked prism.

5. Measurement Result Analysis

All data were analyzed using IBM SPSS (Ver. 23 for windows, SPSS Inc, Chicago, IL, USA). Repeated measures ANOVA was performed to assess changes in postural control factors according to the effect of the yoked prism set in different directions, and when $p < 0.05$, it was judged that there was a statistically significant difference.

Results

1. Changes in stability index after wearing a yoked prism

Table 1 shows the change in the general stability index after inserting 3 types of yoked prisms in the basal direction on all 27 subjects. Among the three yoked prism directions, the stability index increased significantly in the vertical-yoked prism wearing condition ($p = 0.018$ for without prism vs. yoked prism 2Δ , $p = 0.044$ for without prism vs. yoked prism 4Δ) and the diagonal-yoked prism wearing condition ($p = 0.012$ for without prism vs. yoked prism 2Δ). In the horizontal-yoked prism wearing condition, there was no significant change compared to before the prism was worn.

Table 1. Changes of stability index after wearing each yoked prism

Test conditions	Base direction of yoked prism		
	Horizontal (R-BI/L-BO)	Vertical (OU-BD)	Oblique (OU-base135°)
<i>Without prism</i>	15.07±3.61 ^a	15.07±3.61 ^a	15.07±3.61 ^a
<i>Yoked prism 2Δ</i>	16.67±3.99 ^b	16.72±5.03 ^b	17.60±6.14 ^b
<i>Yoked prism 4Δ</i>	15.92±5.83 ^c	16.81±5.37 ^c	16.74±5.37 ^c
<i>F/p-value</i>	3.068/0.064	3.596/0.038	4.115/0.024
<i>post-hoc</i>	-	a<b(p=0.018) b=c(p=0.897) a<c(p=0.044)	a<b(p=0.012) b=c(p=0.281) a=c(p=0.095)

Data are expressed as Mean ± standard deviation

^{a,b,c}: subgroups by LSD post-hoc analysis

* $p < 0.05$

2. Changes in fall risk index after wearing a yoked prism

Table 2 shows the change in the fall risk index after inserting three representative yoked prisms in the basal direction. Among the three conditions according to the direction of the yoked prism, the fall risk index significantly increased in the diagonal-yoked prism condition ($p = 0.028$ for without prism vs. yoked prism 2Δ). However, there was no significant change in the horizontal-yoked prism and vertical-yoked prism wearing conditions compared to before the prisms were worn.

Table 2. Changes of fall risk index after wearing each yoked prism

Test conditions	Base direction of yoked prism		
	Horizontal (R-BI/L-BO)	Vertical (OU-BD)	Oblique (OU-base135°)
Without prism	3.85±3.88 ^a	3.85±3.88 ^a	3.85±3.88 ^a
Yoked prism 2Δ	4.96±3.94 ^b	6.00±4.84 ^b	6.54±4.25 ^b
Yoked prism 4Δ	3.70±3.58 ^c	5.11±4.31 ^c	5.85±4.93 ^c
F/p-value	1.828/0.171	3.076/0.061	4.011/0.028
post-hoc	-	-	a<b(p=0.003) b=c(p=0.483) a=c(p=0.085)

Data are expressed as Mean ± standard deviation

^{a,b,c}: subgroups by LSD post-hoc analysis

* $p < 0.05$

3. Changes in synchronization index after wearing a yoked prism

Table 3 shows the changes in the six synchronization indices according to the effect of the yoked prism in each yoked prism directional condition. Results showed the effect of the horizontal-yoked prism and vertical-yoked prism on the synchronization index was not found. However, when a diagonal-yoked prism was worn, among six synchronization indices, AB ($p = 0.007$ for without prism vs. yoked prism 2Δ, $p = 0.005$ for without prism vs. yoked prism 4Δ), CD ($p = 0.007$ for without prism vs. yoked prism 4Δ), and BD ($p = 0.027$ for without prism vs. yoked prism 4Δ) showed a marked decrease compared to before the prisms were worn.

Table 3. Changes in synchronization index after wearing each yoked prism

Base direction of yoked prism		Schematic diagram of six synchronization					
		AB	CD	AC	BD	AD	BC
Horizontal	Without prism	-827.15±203.11	-881.25±130.77	639.52±318.84	782.05±175.75	-826.90±155.01	-829.45±141.22
	BI/BO 2	-832.60±179.69	-836.26±133.11	602.66±261.61	747.03±221.62	-811.69±132.64	-818.75±151.71
	BI/BD 4	-830.50±124.83	-790.82±201.56	571.69±315.67	722.67±205.67	-830.04±162.62	-812.48±172.12
	F/p-value	0.09/0.988	2.216/0.123	0.415/0.632	0.864/0.422	0.132/0.863	0.092/0.910
	post-hoc	-	-	-	-	-	-
Vertical	Without prism	-827.15±203.11	-881.25±130.77	639.52±318.84	782.05±175.75	-826.90±155.01	-829.45±141.22
	BD 2	-798.04±174.09	-826.93±136.50	629.52±205.67	722.27±255.63	-857.29±109.62	-816.59±184.51
	BD 4	-787.43±169.89	-858.63±163.43	594.18±263.13	765.02±195.41	-809.66±143.82	-852.92±118.26
	F/p-value	0.525/0.581	1.120/0.331	0.257/0.761	0.569/0.573	0.955/0.385	0.394/0.646
	post-hoc	-	-	-	-	-	-
Oblique	Without prism	-827.15±203.11 ^a	-881.25±130.77 ^a	639.53±318.84	782.05±175.75 ^a	-826.90±155.01	-829.45±141.22
	Base 135 2	-825.26±182.85 ^b	-807.96±249.79 ^b	593.00±354.41	750.42±241.09 ^b	-838.81±135.63	-809.83±236.88
	Base 135 4	-638.58±395.25 ^c	-718.09±242.81 ^c	461.92±419.38	640.68±303.26 ^c	-817.99±233.66	-833.14±111.60
	F/p-value	4.643/0.019	4.244/0.020	2.014/0.144	3.364/0.044	0.116/0.882	0.145/0.837
	post-hoc	-	-	-	-	-	-

	<i>post-hoc</i>	a>c (p=0.007), b>c(p=0.005)	a>c(p=0.007)	-	a>c(p=0.027)	-	-
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Data are expressed as Mean ± standard deviation

^{a,b,c}: subgroups by LSD post-hoc analysis

* $p < 0.05$

Discussions

1. Effect of vertical-yoked prism on postural control

In this study, when yoked prisms experimentally induced changes in spatial perception to the horizontal, vertical, and diagonal directions, it was found that spatial perception changes in the vertical and diagonal directions temporarily induce negative effects on postural stability (Table 1). The visual system has difficulty distinguishing between exocentric motions and self-motions related to egocentric motions.^[14] For example, if you are sitting in a car at a stop sign and the car next to you moves, your brain may misinterpret the visual information that your car is moving. The somatic system responsible for postural control provides the central nervous system with body position and motion information in relation to the support surface. However, when standing on a non-horizontal surface such as a ramp, it interferes with establishing a vertical static posture with respect to the surface.^[14] The egocentric spatial change by the BD-yoked prism added in this study makes the object appear to be floating upwards and looking far away. If you recognize the space on a flat ground, you get the feeling of going up a slope.^[15] When visual information including this change in spatial perception is transmitted, the brain can interpret that the surface a person is standing on is not flat. As a result, the somatosensory receptors of the lower extremities undergo a process of re-adjusting the standing posture with respect to the ground. Posture sway increases and postural stability is judged to be temporarily reduced in the process of reestablishing sensory integration.

2. Effect of diagonal-yoked prism on postural control

Visual information provides information about the position and movement of the head in relation to surrounding objects, and also provides a criterion for verticality. This is because many objects surrounding the human living environment are vertically aligned.^[16] In a previous study by the authors, an examination of the effect on postural stability according to the direction of the correction axis of uncorrected astigmatism showed that postural stability deteriorated when uncorrected oblique astigmatism was induced compared to with-the-rule astigmatism or against-the-rule astigmatism.^[17] Kim^[18] reported that when gaze movement is induced, a change in spatial perception also occurs, which temporarily impedes sensory integration. Based on the results of our previous studies and this study, it was confirmed that the change in the diagonal direction among the changes in spatial perception felt by humans was the factor that most negatively affected postural control ability. This tilted spatial perception change acts as a visual stimulus that complicates the sensory integration re-establishment process and adaptation process for human postural control. Based on the results shown in Table 2, postural stability was reduced and the risk of falling was increased.

3. Synchronization Analysis and Clinical Considerations

The synchronization index analyzes the interaction of the weight distribution changes on the entire left foot and the entire right foot, and on the forefoot and heel of each foot.

This study intended to support the investigation of what causes the increase in stability index and fall risk index through the change in the synchronization index after the yoked prism is worn.

Looking at the changes in the six synchronization indices before and after wearing each yoked prism, when wearing a diagonal-yoked prism, the synchronization ability between AB (entire left foot), CD (entire right foot), and BD (left-right forefoot) was found to decrease compared to before wearing (Table 3). As mentioned above, if the postural control ability is normal, the absolute value of the synchronization index is 700 or more, and the absolute value of below 700 means that the synchronization ability between each foot area is reduced. In particular, if there is a knee or ankle injury or a disease of the cerebellum or cerebrum, the synchronization index is sometimes measured as an absolute value of lower than 200.^[19]

We previously also reported that after wearing corrective glasses, the AC and BD items, which reflect the ability to synchronize the left and right heels and left and right toe, were significantly improved compared to prior to correction.^[20] On the contrary, it was analyzed that the spatial perception change towards the diagonal direction experimentally induced in this study acted as a factor that temporarily impeded the interaction and coordination between visual information and the lower extremities. Based on these results, it was proved that the diagonal-yoked prism had a more negative effect on postural control than the horizontal and vertical yoked prisms.

In order to avoid double vision, patients with strabismus or nystagmus may have anomalous head posture such as turning the face, raising or lowering the chin, and tilting the head.^[21] Yoked prism treatment induces gaze movement by positioning both eyes in the same basal direction, so that people with anomalous head posture can maintain binocular vision even in a normal face position.^[7] Visual information does not play an absolute role compared to somatic information sent from the lower extremities in balancing the static posture, but it actively contributes.^[22,23] Lee and Lishman^[24] reported that as age increases, the information processing ability from the foot and ankle joints decreases, so that the dependence on visual information for balancing becomes higher. Accordingly, when trying to prescribe eyeglasses that clinically cause yoked prism, the decision should be made after sufficient examination of the patient's age and postural adaptation.

Conclusion

According to the results of this study, the temporary gaze movement caused by the yoked prism caused the increase in overall body tremor. In particular, when the yoked prism caused the gaze to change towards the vertical or diagonal direction, postural instability increases temporarily. There is possible exposure to the risk of falls depending on the age and physical health status of the person wearing the glasses. Therefore, when attempting to prescribe yoked prism in the clinical optometry field, the decision should be made after sufficient examination of the patient's postural adaptation.

Limitations

Since the results of this study are based on data measured for 32 seconds, additional analysis is required on the adaptation phenomenon according to the time lapse after the yoked prism is worn. In addition, since the effect of yoked prism was experimentally

induced in this study, additional clinical studies are required for clinical application.

References

- [1] Niam, S., Cheung, W., Sullivan, P. E., Kent, S., & Gu, X. (1999). Balance and physical impairments after stroke. *Archives of physical medicine and rehabilitation*, 80(10), 1227-1233.
- [2] Lord, S. R. (2006). Visual risk factors for falls in older people. *Age and ageing*, 35(suppl_2), ii42-ii45.
- [3] Sturnieks, D. L., St George, R., & Lord, S. R. (2008). Balance disorders in the elderly. *Neurophysiologie Clinique/Clinical Neurophysiology*, 38(6), 467-478.
- [4] Odenrick, P., Sandstedt, P., & Lennerstrand, G. (1984). Postural sway and gait of children with convergent strabismus. *Developmental Medicine & Child Neurology*, 26(4), 495-499.
- [5] Bae, J. I., Yu, D. S., & Kim, S. Y. (2020). Effect of optical correction by fully corrected glasses on postural stability. *PLoS one*, 15(7), e0235919.
- [6] Ogle, K. N. (1950). *Researches in binocular vision*.
- [7] Yang, H. G., & Jung, J. H. (2019). Diagnosis and treatment of childhood strabismus. *Journal of the Korean Medical Association*, 62(6), 325-332.
- [8] Stahl, J. S., Plant, G. T., & Leigh, R. J. (2002). Medical treatment of nystagmus and its visual consequences. *Journal of the Royal Society of Medicine*, 95(5), 235-237.
- [9] Karnath, H. O. (1994). Subjective body orientation in neglect and the interactive contribution of neck muscle proprioception and vestibular stimulation. *Brain*, 117(5), 1001-1012.
- [10] Kim J. D., Kim D. H., Kim B. W., & Kim Y. H. (2008). Subjective visuoperception to vertical yoked prisms. *Journal of Korean Ophthalmic Optics Society*, 13(1), 95-99.
- [11] Kim, T. H., Yi, J. H., & Oh, S. G. (2011). Static posture stability evaluation of female elderly using stability evaluation device. *Journal of the Korea Academia-Industrial Cooperation Society*, 12(12), 5518-5524.
- [12] Park, C. S., & Kang, K. Y. (2011). Effect of visual biofeedback simulation training for balance in patients with incomplete spinal cord injury. *The Journal of the Korea Contents Association*, 11(11), 194-203.
- [13] Kang, K. Y. (2012). Effects of Functional Electrical Stimulation Training on Weight Distribution and Synchronization of the Lower Extremity of Patients with Post-Stroke. *Journal of Korean Physical Therapy Science*, 19(3), 9-15.
- [14] Anne Shumway-Cook. (4rd Ed.). (2014) *Motor control*. Seoul: Yeongmunsa. p. 197-203.
- [15] Press, L. J. (1990). Lenses and behavior. *Journal of Optometric Vision Development*, 21, 5-17.

- [16] Anoh-Tanon, M. J., Bremond-Gignac, D., & Wiener-Vacher, S. R. (2000). Vertigo is an underestimated symptom of ocular disorders: dizzy children do not always need MRI. *Pediatric neurology*, 23(1), 49-53.
- [17] Kim, S. Y., Yu, D. S., Moon, B. Y., & Cho, H. G. (2016). Cause analysis in decrease of body stability according to the induced astigmatic blur. *Journal of Korean Ophthalmic Optics Society*, 21(3), 259-264.
- [18] Kim, J. H. (2009). A study on the property of visual perception of interior space according to eye movement-Based on the observation properly according to observation time of the design element. *Korean Institute of Interior Design Journal*, 18(1), 35-42.
- [19] Kohen-Raz, R. (2004) *Tetrax Physician Guide*. Petah Tikva, Israel: Beamed Sunlight, 2-1
- [20] Park, S. C., Yoo, C. W., Park, K. T., Lee, Y. M., & Kim, S. Y. (2021). Fall prevention in older adults after wearing corrected spectacles for distance. *Journal of Korean Ophthalmic Optics Society*, (26)1, 45-51.
- [21] Korean association for pediatric ophthalmology and strabismus. (3rd Ed.). (2013). *Current concepts in strabismus*. Seoul: Naewae-haksool. p. 290-292.
- [22] Schwesig, R., Goldich, Y., Hahn, A., Müller, A., Kohen-Raz, R., Kluttig, A., & Morad, Y. (2011). Postural control in subjects with visual impairment. *European journal of ophthalmology*, 21(3), 303-309.
- [23] Edwards, A. S. (1946). Body sway and vision. *Journal of experimental psychology*, 36(6), 526-535.
- [24] Lee D., Lishman J. R. (1975). Visual proprioceptive control of stance. *Journal of human movement studies*, 1(2),87-95.