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Changes of Ocular Version with Aging in Normal Korean Population

The purpose of this study is to estimate normative values of maximum versions in healthy Koreans and investigate age-associated changes in eye movement, using lateral and vertical version light-reflex (LVR) test. Two hundred forty normal healthy subjects whose corrected visual acuity was better than 20/50 in both eyes, from 4 to 79 yr old (30 subjects in each decade) were studied. Maximum sustained values of dextroversion, levoversion, supraversion, and infraversion in each eye were measured using LVR test. Changes of versions according to age were analyzed. Mean normal value of dextroversion, levoversion, supraversion, and infraversion in normal Koreans was 7.7 mm, 41.6°, 33.9°, and 7.7 mm respectively. Contrary to values of Caucasians, levoversion (adductive movement) was more excessive and infraversion (depression) was smaller in Koreans. All versions were decreased with aging ($P<0.001$ for all). Levoversion had the largest decrease with aging compared with other versions ($P<0.001$, respectively) and infraversion had the least decrease with age than levoversion ($P<0.001$), supraversion ($P<0.001$). All maximal sustained versions were decreased with aging but the ranges of ocular movements in Koreans were different with Caucasians as version least affected and most affected by age was infraversion and levoversion in Koreans. The study standardized normal maximal versions and aging changes of versions in Koreans.

Key Words : *Ocular Version; Lateral and Vertical Version Light-reflex (LVR) Test; Aging*

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INTRODUCTION

Clinical assessment of the range of the eye movements is important in diagnosis and management of strabismus. Ocular versions are synchronous simultaneous movements of the two eyes in the same direction. The direction of the movements from primary position defines these movements as dextroversion, levoversion, supraversion, and infraversion. Careful examination of versions helps to detect the underaction or overaction of the extraocular muscles at various directions of gaze (1). Usually versions have been evaluated with qualitative and subjective criteria of the clinicians. Guiber (2) first described four different subjective grades of underaction or overaction of the medial and lateral rectus muscles, but he assigned no specific features to the grades of overaction or underaction.

Two objective methods of measuring versions were introduced to exclude the subjective component. One is the limbus test of motility of Kestenbaum (3) which intended to determine the shift in relative position of certain fixed points in different gaze positions and the other is the lateral and vertical version light-reflex (LVR) test of Urist (4). The LVR test measures extreme version movement using Hirschberg-type scale. The normal values of this test in Caucasians have been reported (4, 5) and clinical applications were also described (5-7), but there were limited data in Koreans. It is known that Asian people have different anatomical configurations of orbit and lid than Caucasians (8, 9) and these racial differences might affect the version movements, but there were few reports on this relationship.

Most tissues in the human body undergo slow involution with aging and histological examination suggests that this also occurs in the extraocular muscle pulleys (10). In the orbit, such changes might complicate control of eye movements and versions. Some studies have documented the age-related changes in oculomotor functions, such as smooth pursuit (11) and the visually controlled eye tracking systems (saccadic, smooth pursuit, and optokinetic) (12). Vertical eye movements are also known to become impaired with advancing age (13-15). Age of a patient is often overlooked when evaluating the range of eye movements. Furthermore, little was known about the absolute values of version movements in normal Korean elderly.

The purpose of this study is to delineate normal values of maximum versions in healthy Koreans and investigate age-associated changes in eye movement using LVR test. The relationship between version movements and dimensions of palpebral fissure is also documented.

MATERIALS AND METHODS

Subjects

Two hundred and forty normal healthy Korean people, from 4 to 79 yr old who visited department of ophthalmology at Holy Family hospital, the Catholic University of Korea from June to November 2006 were studied. The subjects were grouped according to decade of life as 30 subjects in each decade. All subjects had corrected visual acuity better than 20/50 in each eye. Subjects who had history of previous ocular or periocular surgery, diabetes, and cardiovascular disease were excluded; and none of them had amblyopia, strabismus, ptosis or neurological disorder. This study was conducted in conformity to the tenets of the Declaration of Helsinki. Complete ophthalmic examinations including measurement of ocular alignment with cover-uncover test were performed to confirm orthotropia. Head positions were checked to confirm the absence of abnormal head posture. Maximum sustained values of dextroversion and levoversion using lateral version light-reflex test and supraversion and infraversion using vertical version light-reflex test were measured in each eye.

To find the dimensions of palpebral fissure, palpebral fissure height (FH) and horizontal palpebral length (FW), inner intercanthal distance (ICD) and interpupillary distance (IPD) at the primary position were measured with a transparent ruler. The values of the right eye were selected for each analysis.

LVR measurements

The lateral and vertical version light-reflex test was performed for each eye. Subject's head was immobilized by an assistant and a penlight was directed exactly between the eyes of the subject from a distance of 25 cm. The examiner maintained the light at the center throughout the test and both the patient and examiner kept their heads in the same centered position with relation to each other. The subject then visually tracked a toy on the examiner's finger into maximum sustained dextroversion, levoversion, supraversion and infraversion in each eye. Subjects were asked to maximize their effort into extreme range of gaze and to maintain fixation during the examination. The light reflex on the sclera of the abducted or depressed eye and on the cornea of adducted or elevated eye was noted, measured and recorded as a Hirschberg-type measurement for corneal light reflex (e.g., reference points of 20° at the pupillary margin, 35° at the mid-iris position, and 45° at the corneoscleral limbus, as originally reported by Urist [1, 4]) and as millimeters onto the sclera for the scleral light reflex (1) (Fig. 1). For a sclera light reflex in the semilunar fold, either notes it as "SF" or recorded the number of millimeters from the limbus. To minimize the measurements error, three measurements were recorded at each version of each eye. If a value was greater than 5% different from the other readings at that version, an additional measurement was taken. The largest (maximum) value at each version was used for analysis. The same experienced examiner performed all measurements and verbal encouragement was used to ensure stability of the subject's head and maximum effort into extremes of gaze. The measurements of the right eye were selected for analysis in each case.

For statistical analysis, the measurements of the scleral light reflex were converted from millimeters into degrees. In brief, one millimeter displacement of the scleral reflections from

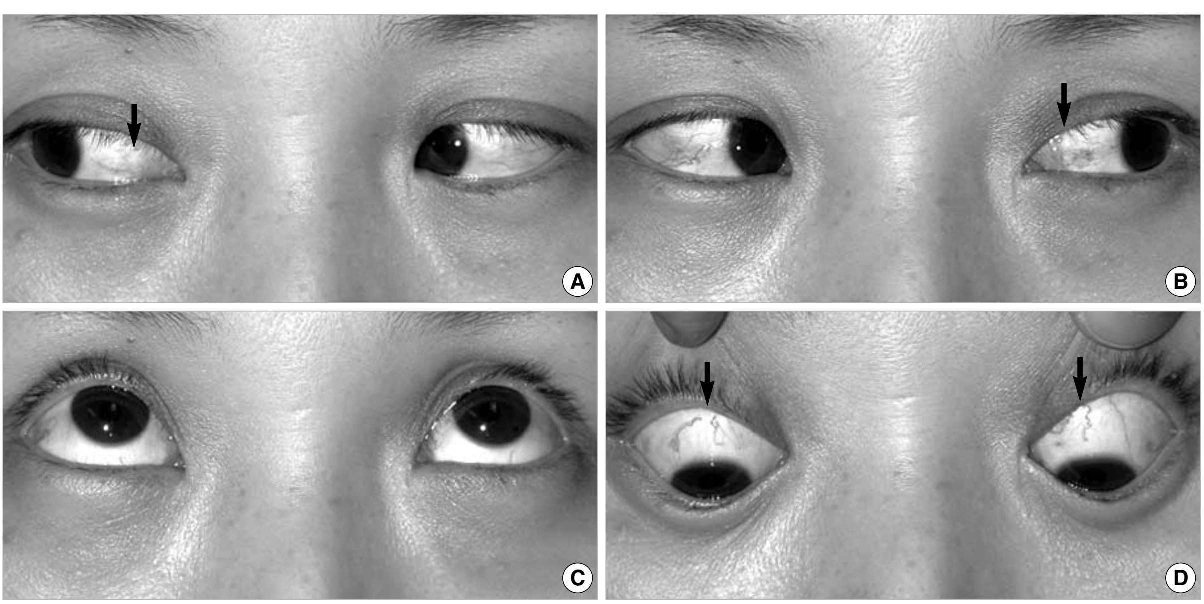

Fig. 1. Photographs of LVR (lateral and vertical version light-reflex) test measurements in dextroversion (A), levoversion (B), supraversion (C) and infraversion (D) of the right eye. Note corneal light reflex and scleral light reflex (arrow point indicates the exact position) in each eye.

the corneoscleral limbus onto the sclera equals to 4.8° of ocular rotation in this geometrical analysis that assuming a scleral diameter of 24.0 mm (standard globe size) (16) (e.g., a LVR measurement of 10 mm on the sclera equals 45° plus [10 mm ×4.8°/mm] which corresponds to 93°). LVR measurements on the sclera were converted into degrees by adding 45° (the ocular rotation of the light reflex to the limbus) to the ocular rotation of the light reflex on the sclera. In addition, for direct comparison of the effect of aging between the four versions, all measurements of LVR were calculated relative to the mean normal measurements of the 3rd decade group and expressed as a percentage for each version (e.g., a LVR measurement of 30° in supraversion was expressed as 79.3% of normal [30°/37.8°×100]).

Statistical analysis

Regression analysis from the SAS program (version 8.0) was used to analyze the aging changes of each type of version.

Table 1. Distribution of age and sex of the subjects

Age (yr)	Male		Female	
	No.	%	No.	%
4-9	20	66.7	10	33.3
10-19	12	40	18	60
20-29	11	36.7	19	63.3
30-39	3	10	27	90
40-49	5	16.7	25	83.3
50-59	7	23.3	23	76.7
60-69	7	23.3	23	76.7
70-79	7	23.3	23	76.7
Total	72	30	168	70

The relationship between horizontal versions and horizontal palpebral length, inner intercanthal distance, and interpupillary distance, and between vertical versions and palpebral fissure height were analyzed using multiple regression analysis.

The effect of aging between versions in different gaze positions were compared using multiple comparison tests. *P* values <0.05 considered to be significant.

RESULTS

Among 240 subjects, 168 (70%) were female and 72 were male. In each decade, the preponderance of females except the 1st decade was homogeneous among the different age groups (Table 1).

The mean (±standard deviation, SD) maximum LVR values in dextroversion, levoversion, supraversion and infraversion of the right eye were 7.7±1.6 mm (range 4-10), 41.6±0.9° (range 20-69), 33.9±4.9° (range 20-45), and 7.7±1.7 mm (range 3-11), respectively in normal Koreans. Fig. 2 demonstrates the mean LVR measurements in millimeters for dextroversion and infraversion versus age of the right eye. Mean LVR values in degrees for levoversion and supraversion of the right eye were shown in Fig. 3. All the values were increased until the 3rd decade, and then decreased with advancing age. In levoversion, 62 subjects (62%) showed large adductive movement over 45° of measurements. The mean values of the 3rd decade group showed maximum in all four movements and the absolute maximum values in detroversion, levoversion, supraversion, and infraversion were 9.1±0.9 mm (range 8-10), 51.3±8.7° (range 35-64), 37.8±3.9° (range 35-45), and 8.9±0.9 mm (range 8-11) respectively.

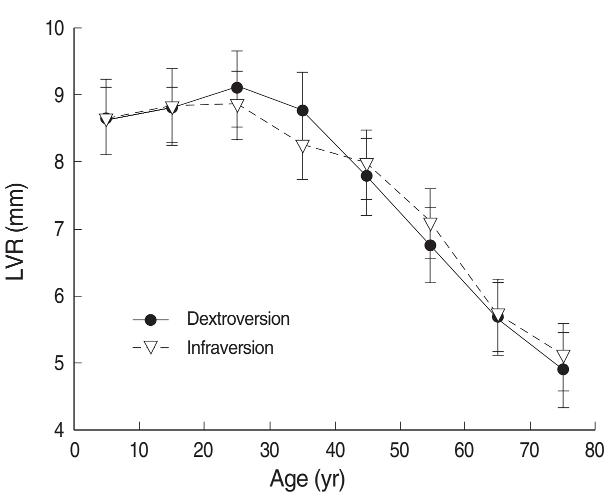

Fig. 2. Mean values of LVR (lateral and vertical version light-reflex) test in dextroversion and infraversion of right eye. Subjects were grouped according to decade of life. All values are scleral light reflex on the right eye. The values are mean±SEM.

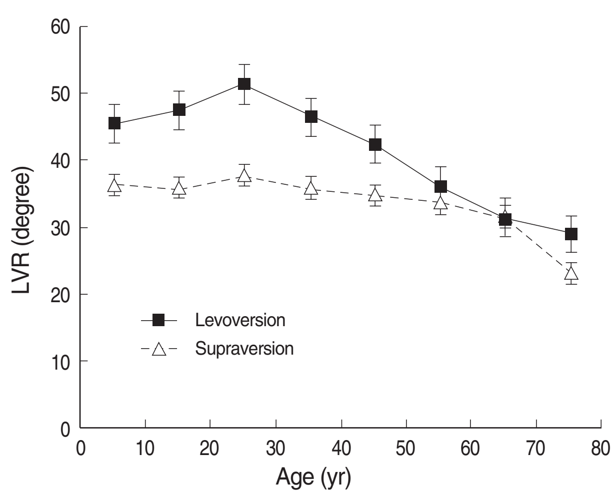

Fig. 3. Mean values of LVR (lateral and vertical version light-reflex) test in levoversion and supraversion of right eye. Subjects were grouped according to decade of life. Values of scleral light reflex on the right eye were converted into degrees. The values are mean ±SEM.

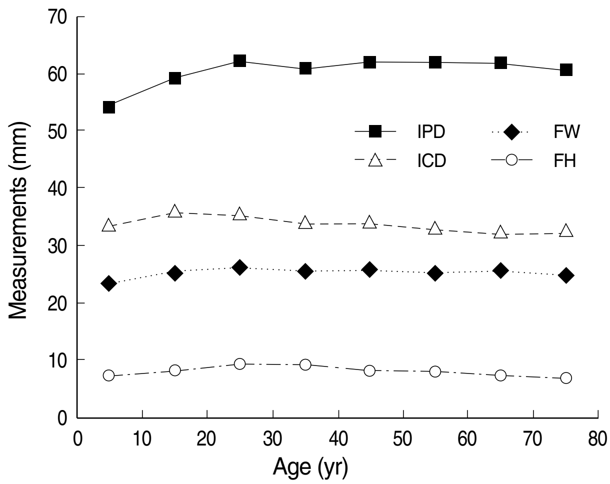

Fig. 4. Mean values of horizontal palpebral fissure length (FW), fissure height (FH) of right eye and inner intercanthal distance (ICD) and interpupillary distance (PD). Subjects were grouped according to decade of life. The values are mean±SEM.

Table 2. Coefficients of regression of LVR values with aging for each version

Ocular movements	Coefficient	*P* value*
Dextroversion	-0.4910	<0.001
Levoversion	-0.9484	<0.001
Supraversion	-0.6506	<0.001
Infraversion	-0.4291	<0.001

*, A regression analysis was performed for each version.

From the 6th decade up, no one showed any normal mean value of LVR in any of the version.

The versions between the two eyes in the same subject were also compared. Asymmetrical versions (difference within 5° or 1 mm) in both eyes were 4.6, 7.9, 0.8, and 2.9% in dextroversion, levoversion, supraversion and infraversion, respectively. No one had a difference of more than 5° between eyes on maximum versions.

The normal mean values of horizontal palpebral fissure length (FW), palpebral fissure height (FH), inner intercanthal distance (ICD), and interpupillary distance (IPD) were 25.8±1.8 mm (range 20-31), 8.2±1.45 mm (range 5-11), 33.9±2.81 mm (range 25-41), and 60.8±3.5 mm (range 46-69), respectively in normal Koreans. FH and ICD were increased from 1st to 3rd decade then showed a decreasing tendency but was not significant. FW and IPD showed no change due to age (Fig. 4).

All LVR values were converted into degrees and calculated as a percentage relative to the mean values of the 3rd decade group to assess the aging changes of versions. All four maximum versions were decreased with aging according to regression lines ($P<0.001$). The coefficients of regression for all versions were described in Table 2.

Fig. 5 plots the calculated mean LVR values in each decade

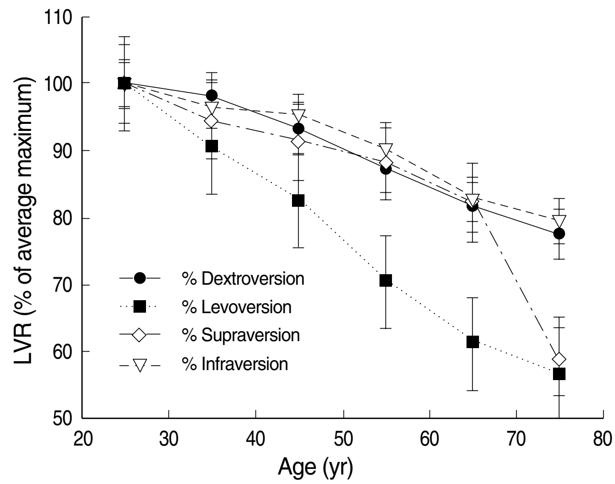

Fig. 5. Calculated mean lateral and vertical version light-reflex (LVR) test measurements in each decade as a percentage relative to the mean values of the 3rd decade group of the right eye. Subjects were grouped according to decade of life. All four versions are decreased with aging ($P<0.001$, respectively by regression analysis). Levoversion is the most decreased with aging ($P<0.001$ for each version type) and infraversion is least affected compared to levoversion ($P<0.001$) and supraversion ($P<0.001$), but not significantly different from dextroversion ($P=0.3036$ by multiple comparison test). The values are mean±SEM.

group as a percentage of mean maximum LVR values. Levoversion (adductive movement) was the most decreased version ($P<0.0001$ for each version type), and infraversion (depressive movement) was the least affected compared to levoversion ($P<0.0001$) and supraversion ($P=0.0002$), but the decline was not significantly different from dextroversion ($P=0.3036$) by aging using multiple comparison test.

There was no significant correlation between FW, ICD, and IPD and horizontal versions ($P=0.1761$, 0.8214, and 0.5433 respectively in dextroversion, $P=0.1566$, 0.6559, and 0.4545 respectively in levoversion), and between FH and vertical versions ($P=0.3093$ in supraversion, $P=0.6580$ in infraversion) in multiple regression analysis. Only the aging affected the version movements significantly ($P<0.001$).

DISCUSSION

The current study used LVR test for evaluating normal objective versions. This study established baseline normative values of maximum versions and aging changes of four version types in a large sample of healthy Koreans. This study is the first, to my knowledge, to quantify the four version movements and correlate them with age objectively in Koreans.

The mean maximal sustained versions were found to be 7.7 mm in dextroversion, 41.6° in levoversion, 33.9° in supraversion and 7.7 mm in infraversion in normal Koreans. All the versions were maximally expressed at the 3rd decade and their absolute values for dextroversion, levoversion, supraversion, and infraversion were 9.1 mm, 51.3°, 37.8°, and 8.9 mm, respectively. The absolute mean normal values and even the maximum values of the Koreans were very different from those of Caucasians which are 10 mm in abduction and depression, and 30° in adduction and elevation (4, 5). Contrary to Caucasians, the mean adductive movement (levoversion in right eye) value was larger and the mean depression and abductive movements (infraversion and dextroversion) were smaller in Koreans. It is unclear why the absolute magnitudes of versions were different from those of Caucasians. A possible explanation may be that Koreans have relatively shallow orbit and less prominent superior orbital rim compared to Caucasians (9). It is speculated that these racial differences might affect the version movements. Low nasal bridge of the Koreans may not obstruct the visual axis of the adducting eye permitting larger adductive movement. Koh and Yoo (17) studied the amounts of horizontal ocular movements in Koreans using three different methods in 2003. Among those three methods, they reported the mean amount of abduction and adduction was 9.85 mm and 34.9° using LVR test. Their values of abduction were much larger than those of this study, but the age range of their subjects were different from this study. Also, they used the Hirschberg test which is used in strabismus evaluation when measuring abduction, and furthermore it was somewhat different from the original LVR test that Urist had described. Although the LVR test utilized the Hirschberg scale, it should not to be confused with the Hirschberg test where the light on which the patient fixates is moved into the fields of gaze. In the LVR test, the light is stationary (4).

It is not exactly known whether the normal values of Caucasians were age matched, but in this study we tried to measure the normal values of maximal sustained version angle for all age groups of healthy Koreans including children. The results showed a gradual increase up to the 3rd decade and then a gradual decrease in both horizontal and vertical version types with advancing age (Fig. 2, 3).

To assess the possible aging changes of each version, the measurements were converted as a percentage relative to the mean values of the 3rd decade. The absolute values were maximal at the 3rd decade. Furthermore, the extraocular muscles and related structures are fully developed and their functions are arrived to the maximum at this age group, so the mean values of the 3rd decade group were chosen as standard values. These proportional values used in this study can make all comparisons easy and simple, and also enables estimating the aging changes more consistent and rapid. All maximum version movements decreased with advancing age, a finding confirmed to be significant by regression analysis ($P<0.001$, respectively) (Table 2). A marked decline appeared around the seventh and eighth decades. These findings may useful to differentiating age-related decreases in version from other neurological diseases, such as progressive external ophthalmoplegia and progressive supranuclear palsy. The normal values of version in accordance with age may also be useful in diagnosing elderly patients with presumed rectus muscle paresis or incomitant strabismus.

Asymmetry between the two eyes also provides important clinical tool for evaluating versions because 84% of healthy subjects in this study showed symmetry between two eyes in all gaze position. The remainders showed asymmetry of less than 5° or 1 mm.

Levoversion and infraversion was the most and least affected by age in Koreans. Adductive movement found to be the most affected with aging in Koreans. Extreme lateral version movements appear to be reflexive in nature but these large adductive movements were constant for all subjects, with 62% of subjects showing measurements over 45°. In Caucasians, higher nose bridge may obstruct the visual axis of adducting eye preventing diplopia. In comparison, it is speculated that the low nasal bridges in Koreans may not obstruct the vision of adducting eye, permitting larger adductive movements. The corneal light reflex is usually nasally displaced approximately 1 mm in primary gaze (19), thus approximately 7° less abduction is needed when compared to adduction before the light reflex falls onto the sclera. Clark and Isenberg (16) studied the range of ocular movements with aging in Caucasians and reported the maximum versions decrease by average of 0.5% to 1.0% per year of life from the third to ninth decade with subjects ranged in age from 23 to 84 yr. The version most affected by age is elevation in their study, contrary to our study. They suggested that the least utilized volitional field of upgaze during normal life attributes to the most affection of elevation by aging.

Studies concerning vertical movements show eye movements become restricted, especially for upgaze. Chamberlain (13) measured the limits of supraduction and infraduction and suggested the gradual "disuse" of upgaze with advancing age might cause the diminution of supraduction in the elderly. But he reported differences due to age were not found in downgaze. Using a keratometer, Yamashiro (14) measured the overall limit of uniocular extent during foveal fixation in elderly subjects, and reported decrease of maximum movements for oldest age group in both depression and elevation. In 2004, Oguro et al. (15) observed vertical eye movements were decreased with advancing age. They also noted significantly smaller upgaze than downgaze and suggested the differences of aging process in vertical gaze were due to different gaze mechanisms. Different neuronal pathways of upgaze and downgaze systems or functional differences between upward and downward gaze systems was suspected for the possible explanation of differences in aging process of the vertical movements. Clark and Demer (18) suggested inferior displacement of the horizontal rectus muscles in older patients, as shown in high-resolution orbital MRI, and that there may be a peripheral mechanism for the reduction in supraduction with age. In this study, supraversion and dextroversion showed similar reduction with aging, but supraversion was relatively well preserved in Koreans. Comparing the two vertical versions, supraversion decreased more than infraversion (multiple comparison test, P=0.0002), a finding similar to previous duction studies.

It is unclear why depression is less affected by aging than the other versions. The striated muscles fibers within extraocular muscles should change and lose functions at same rate. Gravity would not play a substantial role in rotation of the globe downward about its center of rotation. One hypothetical explanation involves the tight coupling of the inferior rectus muscle to the lower lid retractors (19). As the lower lid sags with age, inferior rectus muscle may be stretched inferiorly as well, increasing the resting tone within the muscle. Such an effort may increase the mechanical effectiveness of the inferior rectus to the other muscles.

The current study also measured the normal mean values of horizontal palpebral fissure length (FW) and height (FH), internal intercanthal distance (ICD), and interpupillary distance (IPD). The mean normal measurements of FW, FH, ICD, and IPD were found to be 25.8 mm, 8.2 mm, 33.9 mm, and 60.7 mm, respectively. These findings were comparable to published results of normal values of anthropometric studies in Koreans (20-23). In this study, FH and ICD showed slight decreasing tendency by age and these findings were similar to the report of Park et al. (20). We tired to find out whether the dimensions of palpebral fissure could affect the versions with advancing age. There were no significant correlations between FW, ICD, PD and horizontal versions with aging. There were no significant correlation between FH and vertical versions either. The anatomic characteristics of eyelids and related structures did not affect to versions with aging in Koreans. Aging affected the version movements only (P< 0.001).

Possible limitations of this study include a sampling error related to subjects because they were patients of eye clinic and may be more prone to abnormal eye movements although none had strabismus. True orthotropia is rare and small degree of esphoria or exophoria is a common finding in straight- appearing eyes of normal population. For more accurate determination of the normal versions in Koreans without any effects from heterophoric or heterotropic state, subjects with orthotropia only were strictly selected in this study using repeated cover and cover-uncover test which using adequate fixation objects, reliable cooperation, and wearing refractive correction. For this, total sixth months of preparation time was needed. Another potential bias was the ages of the subjects were not masked from the examiner. The digital photos documenting the light reflex on the globe may compensate for this observer bias. Finally the measurements error of author may affect the results, but the present author had performed the LVR test on more than 1,000 patients prior to beginning the study.

In conclusion, this study standardizes the normal maximum versions and aging changes of versions in Koreans and these in turn make it possible to induce a normal template that utilized fast and easy, simple in clinical office examination for detecting incomitant or paralytic strabismus, especially in elderly patients.

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