THE OPTICAL EFFECTS OF HEAD TILT
ON THE
SPECTACLE CORRECTED ASTIGMAT

AUTHORS

WILLIAM J. BUCKINGHAM

JOHN A. FINN

COLLEGE OF OPTOMETRY

FERRIS STATE COLLEGE

1979

ABSTRACT

It was found clinically that when a group of patients with astigmatic spectacle corrections tilted their heads toward either shoulder, many reported a subjective blurring of the visual acuity chart. The mechanism of this blur appears to be due to the change in the location of the axis of the astigmatic refractive error. This change in the axis location is caused by the compensatory counter-rolling of the eyeballs governed by the labyrinth reflexes.

The topic of this study is based on the following three premises. (1) Upon any postural head tilt toward either shoulder the eyes will counter-roll reflexly in attempt to compensate for the head tilt. (2) With an astigmatic spectacle worn, any head tilt with associated counter-roll of the eyes will result in the movement of the exact correcting cylinder axis. The correct axis of the astigmatic refractive error will rotate an amount equal to the amount of the counter-roll of the eye. (3) Whenever a cylinder axis is placed in error of the true location of the axis, the patient will no longer be perfectly optically corrected.

The above three premises infer the following theory which resulted in this study.

THEORY

When a subject wearing a theoretically exact astigmatic spectacle correction tilts ~~their~~ his head toward either shoulder there is produced an optical error in the correction of the cylidrical refractive error. When a patient with a significantly large spectacle cylindrical correction tilts their head toward either shoulder, there may be a clinically observable and measurable blur produced.

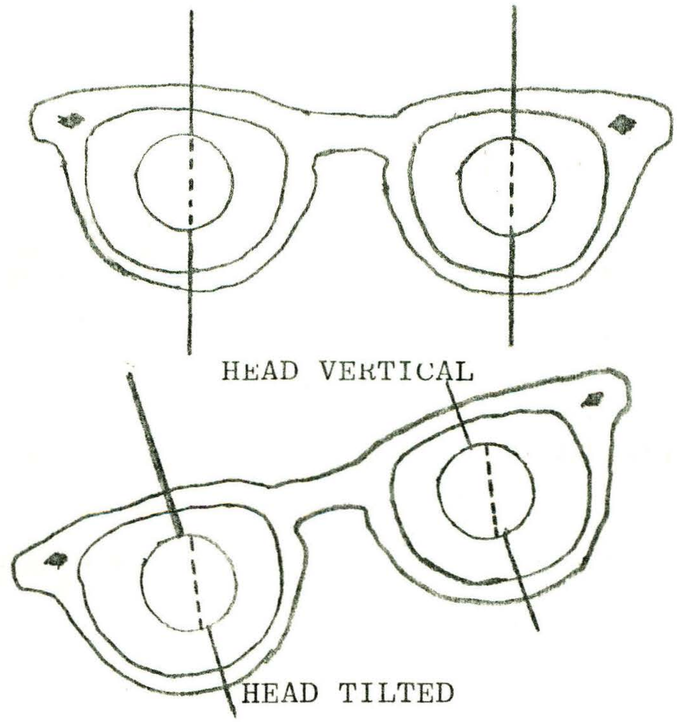


Diagram # 1

------- axis location needed for eye

——— axis location in spectacles

INTRODUCTION

The vestibular labyrinth reflexes constitute the main mechanism initiating the compensatory eye movements that this study is based on. This reflex is divided into two divisions. (1) Static reflexes which are due to changes in the head position with respect to gravity. (2) Stato kinetic reflexes resulting from the movement of the head through space, i.e. acceleration and deceleration. Each labyrinth exerts a continuous tonic innervation which tends to turn and rotate the eyes to the side opposite the head tilt. (i.e. The right labyrinth causes levoversion and levocyclorotation.) Removal of the labyrinth therefore results in the rotation of the eyes toward that side, due to the unopposed action of the other unaffected labyrinth. Only conjugate eye movements are produced by labyrinth reflexes, no disjunctive movements.

The Otolith apparatus also affects static reflex repositioning of the eyes. This reflex is called the Ulricular reflex. It is affected by a change in the position of the head with respect to gravity. At the same time tonus of each of the antagonist muscles is diminished.

Acceleration and deceleration of the head stimulates a statokinetic reflex. There are three semicircular canals within the petrous bone, one of which affects the cycloversional rotation of the eyes. A minimum of 1 to 3 degrees per second is needed to stimulate this reflex. After the acceleration, the eyes return to their normal position.

Tonic neck reflexes also affects the reposition of the eyes when the head is tilted. The impulses reach the oculomotor muscles after proprioception organelles are stimulated. This affect is minimal in man.

The Utricular reflex does not involve innervation to the medial or lateral recti. Only the cyclovertical muscles recieve innervation. The magnitude of the compensational rotation of the eyes due to the head tilt is approximately 7.00 ± 3.10 degrees for a 30 degree head tilt in the ipsilateral eye; and 8.36 ± 2.50 degrees for the contralateral eye. The maximun response is produced by a head tilt of approximately 60 degrees. However, Linwory measured this rotation compensation as being approximately one sixth to one fifth the total amount of the head tilt. In addition a study was done by Cohen with jet pilots in airplanes rolling rapidly, and he found a 20 degree ocular torsional movement. The speed of the vestibulo-ocular compensational eye movements have been measured and found to be as fast as 300 to 400 degrees per second. Experiments conducted in the National Aeromedical Centre in Holland showed that the ratio in arc degrees of the counter-rolling of the eyes to the amount of head tilt was directly proportional to the amount of increase in the G-force acting on the subject.

Although studies and figures vary it seems safe to approximate the magnitude of the counter-roll with a 60 degree head tilt to be between 12 to 15 degrees. And a 45 degree head tilt to cause approximately a 10 degree counter-roll. In accordance with theory we predicted two possible results in a patient whose head is tilted while wearing a significantly high cylindrical correction, whose refractive error is neutralized in the primary position.

(1) The subjects vision will become blurred to some degree.

(2) There is some unknown mechanism preventing this blur.

Our experimental testing with recently corrected patients at the Michigan Reformatory in Ionia was intended to prove whether or not we could measure a subjective and objective change in visual acuity, and attempt to quantify this blur. The results of this testing and procedures used are as follows.

METHODS

The subjects included in this study (N=24) were residents of the Michigan Reformatory Correctional Facility, optometry stundents, and staff of the infirmary at the reformatory. The ages ranged from 19 to 48, with the mean being 27. All subjects were recently corrected for their refractive error (wihtin 1 year), so it was assumed that all refractive corrections were correct in power and axis.

The psychometric series (Landolt C) was used for measurement of visual acuity to minimize the possibility of memorization, also to eliminate horizontal and vertical components in the VA chart. Each slide consisted of 8 characters per Snellen designation. The passing criterion was established at 5 correct out of a possible of 8.

The study subjects were divided into four groups according to cylindrical power in their spectacle correction (See Table I)

	No. of Subjects	Amount of Spectacle Cyl. Power
Group A	5	0.00 to 0.75D
Group B	7	1.00 to 1.75D
Group C	6	2.00 to 2.75D
Group D	6	Greater than 2.75D

TABLE I

The acuity was measured by starting at 100% correct on a slide and then decreaseing the size of the target until the subject failed the criterion. Then the last correct Snellen designation was taken as the corrected acuity.

TEST

The following procedures were performed on every subject.

(1) The refractive correction of each subject was placed in a trial frame.

(2) The visual acuity was recorded for each subject, both binocularly and monocularly (OD only), in the primary position (head vertically straight).

(3) The cylinder axis of the OD was rotated counter-clockwise and the subject was asked if he noticed any change in the clarity of the target. (This was done to determine if the subject could detect the blur from the correcting cylinder being off axis with respect to the ocular refractive cylinder axis.)

(4) The visual acuity was recorded, both binocular and monocular (OD only), with the head tilted 45 degrees toward the right shoulder.

(5) The subject was asked to make a subjective comparision between the clarity of the target when the head was vertically straight and tilted 45 degrees, in both the binocular and monocular state.

RESULTS

In group A subjects (0.00 to 0.75D of cylindrical correction), 40% reported no change subjectively in VA, and none could be objectively measured. While 60% reported a subjective decrease in VA, but still none could be measured objectively.

In group B subjects (1.00 to 1.75D of cylindrical correction), 28% reported no subjective or objectively measured change in VA; 28% reported a subjective decrease in VA but it could not be objectively measured; while, 44% reported both a subjective and objectively measured decrease in VA. It should be noted that none of the reductions in VA was a whole line, most went from $20/20^{-0}$ to $20/20^{-3}$.

In group C subjects (2.00 to 2.75D of cylindrical correction), 17% (one person) reported an increase in VA both subjective and objective; 17% reported a subjective decrease in VA but it could not be objectively measured; and, 66% reported a subjective and objectively measured decrease in VA, with 80% of these being a one line decrease, i.e. 20/20 to 20/25.

In group D subjects (greater than 2.75D cylindrical correction), 84% reported a subjective decrease in VA, while 100% reported a objectively measured decrease in VA.

SUMMARY OF DATA

Change in VA with head tilt of 45°	GROUP A	B	C	D
No change in VA subj. or obj.	40%	28%	17%*	0%
Subj. decrease in VA, but not obj. measureable	60%	28%	17%	0%
Obj. measured dec. in VA, but not reported subj.	0%	0%	0%	0%
Both subj. and obj. decrease in VA	0%	44%	66%	100%

TABLE III

*One subject reported a subjective and objectively measured increase in VA with the head tilted. We attributed this to be due to improper cylindrical correction, which was later proven to be true.

As can be seen from the data, as the cylindrical spectacle power increases there in an increase in the subjective and objectively measured decrease in visual acuity! This change appears to be linear, but there was not enough samplings to justify that particular claim.

The mechanical rotation of the cylinder axis in the trial frame prior to tilting the head was found to be directly related to the subjective report of blur. It was found that 93% of the subjects who reported blur with rotation, also reported a subjective blur upon tilting the head.

It was also noted that twice as many subjects reported more blur in the monocular state than in the binocular state.

CONCLUSION

As the data indicates there appears to be a consistant clinical observation of blur upon the head tilting of the patients tested. This is primarilly noticed in higher cylindrical corrections, greater than 1.00D. A smaller subjective blur was noticed by the subjects with lower cylindrical correction, less than 1.00D, but it was less than a one line decrease in visual acuity. It should be noted that the numerical location of the cylindrical correction theoretically makes no difference in the amount of blur produced by a head tilt. The axis location could however, affect a measured change in the Snellen acuity testing due to the vertical and horizontal orientation of most all of the Snellen componants. That is why the Landolt C was used for this particular study.

It is obvious that only patients with moderately high cylindrical corrections, along with a significant head tilt could result in a blur which would cause any real handicap in visual acuity. As stated before, there must be a minimum of 1.00D of cylinder for any objectively measured VA decrease to be reported. But even with 0.50D of cylinder, there is a blur reported in some patients. The presence of this blur could become practically significant in several clinical situations. A person with a compensatory head tilt due to a paretic extraocular muscle or cervical spine or neck muscle deformation must be refracted in the habitual head tilt position in order to get the correct cylinder axis. Also, persons with significantly high cylindrical corrections who are bed ridden may notice a change in acuity in certain viewing angles away from the prone position.

The study noted before with the jet pilots is interesting when correlated to this study. The increased force of the apparent gravity due to rolling and banking of the plane can cause exaggerated counter-rolling of the eyes. This could theoretically cause a very significant blur in the astigmat corrected with spectacles.

The clinical solution to reduce this blur caused by head tilting and gravitational forces is the application of a rigid contact lens. With a contact lens in place on the cornea, the total amount of corneal astigmatism will be neutralized no matter what the head position. If the patient wears a spherical contact lens and there is some residual astigmatism, the axis of this residual astigmatism will change on head tilt but the amount of power will stay the same. Therefore, the amount of blur should stay the same. The lens of choice would be a bitoric lens because it would rotate with the eye, where a prism ballest lens would be effected by the gravitational force on the head tilt.

SUMMARY

The compensatory counter-rolling of the eyeballs, which occurs when the head is tilted toward a shoulder, should theoretically cause a decrease in visual acuity. This is caused by the eyes refractive cyliner axis rotating away from the spectacle cylinder axis. It was found that there is a subjectively noticed reduction in acuity along with an objectively measured decrease in acuity. The objectively measured acuity changes (one line worse on the Snellen chart) were only noticed in higher cylindrical powers, where the subjective changes in acuity were noticed with almost all powers of cylindrical corrections. As stated earlier, there are clinical situations where this reflex must be considered in the application of prescription lenses with high astigmatic corrections.

APPENDIX A

Fig. 1

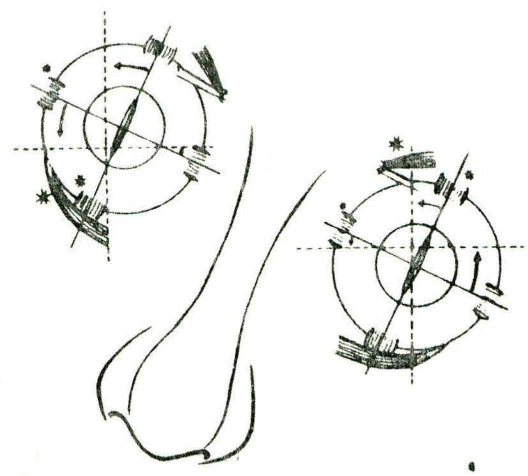
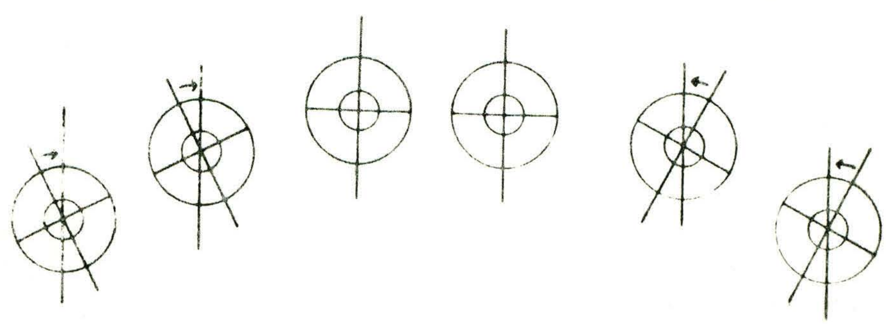


Fig. 2



Figures 1 & 2. Tilting of the head to the left produces intorsion of the left eye and extorsion of the right eye.

APPENDIX B

The amount of optical error predicted by the theory depends on two major variables.

(1) The amount of cycloversional counter-roll that occurs with the head tilt

(2) The amount of cylindrical correction needed by the patient.

The dioptric value or amount of the error can be predicted mathematically through the use of the formula:

$$E = S + C\sin^2\theta$$

E = the dioptric power in the axis meridian
S = the sphere componant of the spectacle correction
C = the cylinder componant of the spectacle correction
θ = amount of the counter-roll of the eye

The calculated E value subtracted from the original dioptric power in the axis meridian will equal the dioptric error in that meridian produced by the head tilt.

REFERENCES

Glaser, Joel S., "Neuroophthalmology", Medical Dept., Harper & Row Publishers, Inc., Hagerstown, MD., 1978

Hoyt, Walsh, "Clinicalneuro Ophthalmology", Vol. 1, III ed., Williams & Wilkins. Co., Baltimore, MD., 1969

Moses, Robert A., "Adlers Physiology of the Eye", 6th ed., C.V. Mosby Co., Saint Louis, MO., 1975

Parks, Marshall M., "Ocular Motility and Strabismus", Medical Dept., Harper & Row Publishers, Hagerstown, MD., 1975