SCIENCE SET
OPEN ACCESS PUBLISHERS

Research Article

Science Set Journal of Ophthalmology and Eye Care

The Relationship between AC/A Ratio and Age

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Submitted: 08 Oct 2022 **Accepted:** 15 Oct 2022 **Published:** 31 Oct 2022

***Citation:** Raj Kumar (2022) The Relationship between AC/A Ratio and Age, Sci Set J of Opthamology & Eye Care, 1(1), 01-04.*

Abstract

To obtain an understanding of the relationship between accommodation and convergence, one must keep in mind the elements involved in the process.

These elements are:

(1) The change in stimulus to accommodation,

(2) The peripheral and central nervous system mechanisms that elicit and transmit the impulses and provide the motor impulses to the inner and outer muscles of the eyes, and

(3) The effect or organs that provide the responses (the change in refraction of the eye and the change in position of the globe).

These factors must be briefly analyzed. So far in this discussion of AC/A ratio determination, the degree of convergence achieved has been related to the stimulus to accommodation (the dioptric power of the lenses used or the change in viewing distance). This relationship has been termed the stimulus AC/A ratio by Alpern and coworkers.

In laboratory studies one can arrange a haploscopic device so that the stimulus to accommodation, the response to the stimulus (the change in refraction of the eyes), and the change in position of the eyes can be determined simultaneously. With such an arrangement, one can relate the change in convergence to the stimulus to accommodation as well as to the accommodative response. The AC/A ratio related to the accommodative response has been termed the response AC/A ratio.

This ratio differs from but parallels the stimulus AC/A ratio reported by Alpern and coworkers and by Ripps and coworkers. Alpern and coworkers stated that the response AC/A ratio could be predicted with reasonable accuracy by multiplying the stimulus AC/A ratio by a factor of 1.08. In other words, the response AC/A ratio exceeds the stimulus AC/A ratio by about 8%. Presumably, this applies only to non presbyopic adults. From the clinical standpoint, to determine the response AC/A ratio is impractical and unnecessary. The clinician must be concerned with the stimulus AC/A ratio. Various investigators have shown that the convergence response is generally linear and the stimulus is in the range within which the observers can respond. However, it is evident that a given stimulus to accommodation need not always elicit the required amount of change in refraction of the eye (the accommodative response), for example, in presbyopic patients. Although the impulses to accommodation sent out by the central nervous system may be adequate, or even excessive, and may result in adequate contraction of the ciliary muscle, the accommodative response will not be linear with the stimulus because of hardening of the crystalline lens.

"RELATIVE" CONVERGENCE AND "RELATIVE" ACCOMMODATION.

The observation that, within limits, one can force convergence by the use of prisms without blurring the fixated object and, conversely, that one can change accommodation by means of lenses without causing diplopia suggested to Donders and his followers that there is an elastic relationship between accommodation and convergence. The limits within which convergence and accommodation could be changed without producing blurring or diplopia were termed the "amplitude of relative convergence" and the "amplitude of relative accommodation." This teaching has prevailed until recently, but it has now been shown that every change in accommodative stimulus produces a change in convergence.

The limits within which single vision is possible with changes in accommodative stimulus depend not on an elastic relationship between accommodation and convergence but on the availability of fusional amplitudes that enable one to cope with the change in the position of the eyes. This concept is of basic importance for the understanding of binocular cooperation and of the neuromuscular anomalies of the eyes [2].

Keywords: Accommodation; Convergence; AC/A Ratio; Presbyopia; Fusional amplitudes

Introduction

As we know that in an emmetropic eye, parallel rays of light coming from infinity are brought to focus on the retina, with accommodation at rest. Our eyes have been provided with a unique mechanism by which we can even focus the diverging rays coming from a near object on the retina in a bid to see clearly. This mechanism is called accommodation. In it there occurs an increase in the power of the crystalline lens. The nearest point at which a small object can be seen clearly is called near point or punctum proximum.The distant (farthest) point is called far point or punctum remotum. The distance between the near point and the far point is called range of accommodation. The difference between the dioptric power needed to focus at near point (P) and to focus at far point(R) is called amplitude of accommodation. Thus, A=P-R. When the object is accurately focused monocularly, often the object somewhat near and somewhat farther away are also seen clearly without any change in accommodation . This range of distance from the eye in which an object appears clear without change of accommodation is termed as depth of field.

Depth of field reduces the necessity for precise accommodation. The range at the retina in which an optical image may move without impairment of clarity is termed as depth of focus. The depth of field and depth of focus are markedly influenced by the diameter of the pupil. So depth of field is inversely proportional to the pupil size. Size of the blur circle produced on the retina is proportional to pupil size. Depth of field should not be mistaken for accommodation. The apparent range of accommodation also includes depth of field and tolerance of blur (i.e. depth of focus).

Accommodation is the result of change in the form of the lens brought about by contraction of the ciliary muscle.3 There is no disagreement that a change in the shape of the lens—an increase or decrease incurvature and thickness of its central parts that produces an increase or decrease in the dioptric power of the eye—is the basic mechanism underlying accommodation. Nor is there any disagreement that this change in the shape of the lens is caused by a contraction of the ciliary muscle.

Whether this contraction produces loosening of the zonular fibers or tightening with forward pull-on the choroid and increased intra vitreal pressure,affecting the periphery of the lens, or some other more complex effects, is not essential to this discussion. It is sufficient to know only that the change in shape of the lens, resulting from a contraction of the ciliary muscle, represents the peripheral mechanism of accommodation set in motion by a central mechanism of accommodation, which in turn responds to a stimulus to accommodation. The stimulus to accommodation is the blurred retinal image. The afferent pathway is represented by the visual pathway up to area 17 and continues to area 19. The ciliary muscle is innervated by cranial nerve III, with the majority of the fibers being relayed through the ciliary ganglion from the midline nucleus (Edinger-Westphal) of the Oculomotor complex. The projection of area 19 to the midbrain oculomotor complex is by way of the internal corticotectal tract, but no details of the supranuclear connections are known. Jampel succeeded in increasing refraction in both eyes of the macaque accompanied by convergence and in some cases pupillary constriction by unilateral faradic stimulation of area 19 [2].

Accommodation is a unique mechanism, by which our eyes can even focus the diverging rays coming from a near object on the retina in a bid to see clearly. Assessment of amplitude of accommodation (the difference between the dioptric power needed to focus at near point 'P'and far point 'R' i.e. A=P-R) in practice can be made either by measurement of near point of accommodation (NPA) or by use of minus lenses as:

- NPA is the closest point at which small objects can be seen clearly. It is also called 'near point' or 'punctum proximum'.
- NPA is measured using a near point rule such as the RAF rule or Prince's rule.

To determine the NPA, a sliding target with 6/9 letters numbers or fine lines is moved from or towards the eye until the closest point is found at which it still can be seen clearly. During the examination, the patient has to wear his full optical refractive correction. The NPA is determined first for each eye separately and then for both eyes together. The NPA is measured in centimeters marked on one side of the instrument bar. The side of the bar marked in diopters will indicate the amplitude of accommodation in diopters. The third side of the bar shows the age corresponding to the accommodation.

Aim

- To determine the relationship between AC/A ratio and age.

Material

- Prism bar, trial lens, Maddox rod, near & distance target.

Inclusion Criteria

- Age group between 17 to 45 yrs.
- Subject with normal binocular vision.
- Amplitude of accommodation (push up method) normal for their age.
- Visual acuity equal in both eyes and corrected to at least 6/6
- Astigmatic correction of more than +/- 0.75D.

Exclusion Criteria

- Any ocular pathology
- Any ocular surgery.
- Methodology
- 35 subjects between the age group 17 to 45 yrs were randomly selected and screened.
- A detailed eye examination is done with BCVA. Anterior segment evaluation with slit lamp bio-microscope.
- Posterior segment is evaluated with an indirect ophthalmoscope.
- AC/A ratio is measured with the Heterophoria method.
- Heterophoria Method: This method consists of measuring the deviation in distance fixation (optical infinity) with full correction of a refractive error, if one is present, on the assumption that no accommodation is exerted under these circumstances. The deviation then is measured at near vision distance (33 cm or 3D) on the assumption that the convergence exerted is caused wholly by the accommodation convergence synkinesis. The AC/A ratio is obtained from the equation, AC/A=IPD+Δn-Δd/D.

Where,
IPD = interpupillary distance (in centimeter)
nΔ = Deviation at 33 cm or 3 dioptre distance in prism dioptres
dΔ= Deviation at 6 meter distance in prism dioptres D
= the fixation distance near dioptres.

Note

- Esodeviation is denoted by positive (+) and exodeviation by negative (-) sign.
- This equation is explained by the fact that the convergence requirement equals the interpupillary distance multiplied by the fixation distance in diopters and that the change in deviation from distance to near fixation equals Δn-Δd.
- Interpupillary distance (IPD) is measured with the help of pupilometer and IPD rule.
- Near deviation and distance deviation (deviation at 6 meter) is measured with prism bar cover test and Maddox rod test.

Results

- A moderate linear relationship between AC/A ratio with age.
- AC/A ratio increases with age.
- A significant linear correlation is present between AC/A ratio and age. (r^2=0.346, P=0.05), although some variability about the regression line was present.

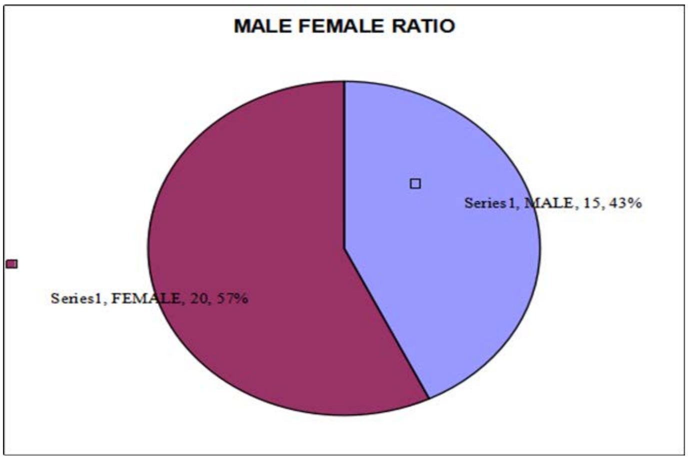

Figure 1

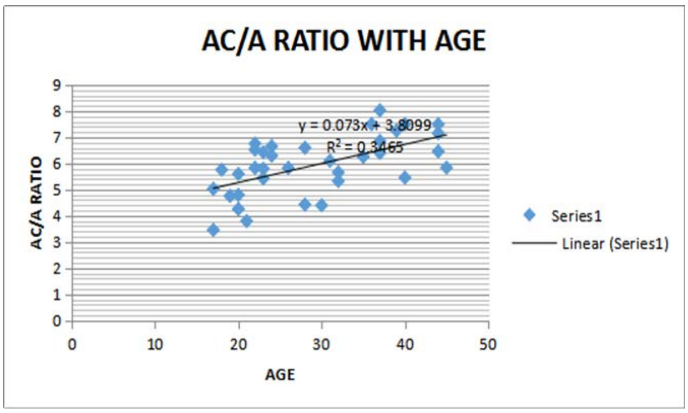

Figure 2

Where,
Series1 =AC/A RATIO X axis = AGE (in years)
Y axis = AC/A RATIO (in ΔD)

Discussion

The results for the 35 subjects showed the response AC/A ratio to increase with age (Fig4). Previous studies had shown little change in response AC/A before age 40 and an exponential increase after that age. The difference in results may be due to the fully objective techniques used in this study. An increase in the AC/A ratio between 20 and40 years of age is consistent with the finding that a considerable decrease in the response amplitude of the increase in AC/A with age may have some ramifications on the mechanisms underlying presbyopia. The mechanism of presbyopia is still not well understood, and, although different theories attempt to explain it, not one is entirely consistent with existing evidence. Current theories of presbyopia are as follows:

1. The Hess-Gullstrand theory1617 attributes presbyopia to age-related changes in the lens, with the amount of ciliary muscle contraction required for a particular change in accommodation remaining the same as age increases, provided that this level is within the amplitude limit.
2. The Fincham theory is similar to the Hess- Gullstrand theory in claiming that presbyopia is due to the lens being less easily deformed with increasing age, but the maximum ciliary muscle contraction is required for maximum accommodation at all ages.
3. The geometric theory posits that presbyopia is attributed to changes in the size and shape of the lens that make the zonules apply tension more parallel to the surface of the lens. Changes in zonule tension will thus have smaller effects on lens shape.
4. Extralenticular theories claim that presbyopia is caused by weakening of the ciliary muscle or by loss of elasticity of zonules or ciliary body and choroid components.

The Hess-Gullstrand theory is distinct from other theories in one important respect. According to this theory, with increasing age there is an increasing excess of ciliary muscle contraction beyond the ability of the lens and the capsule to respond to it. For all other theories, the maximum possible amount of ciliary muscle contraction is necessary to produce maximum accommodative amplitude beyond the age at which this amplitude begins to decline. Support for the Hess-Gullstrand theory is provided by evidence that the ciliary muscle continues to contract at stimulus levels greater than the maximum amplitude of accommodation. Ciliary muscle activity has been assessed from electrical impedance in the equatorial region of the lens, the electrical impedance possibly reflecting changes in blood flow. Impedance changes continue to occur after the maximum accommodation has been reached. However, this evidence is

equivocal; Bito and Miranda suggested that blood flow might be altered by neural activity concomitant with an accommodation effort, irrespective of ciliary muscle activity. The Hess-Gullstrand theory predicts that accommodation-convergence relationships remain unchanged throughout life (within the accommodation limit). If the same effort of ciliary muscle contraction is needed to produce a given change in accommodation at all ages, this can be expected to stimulate a similar level of convergence change. Similarly, if a given level of convergence simulates the ciliary muscle to a given degree of contraction at all ages, this produces the same change in accommodation. As found in this and in previous studies, the AC/A ratio increases with age. This is evidence against the Hess-Gullstrand theory; all the other theories of presbyopia predict the direction of changes found in the studies. The prediction regarding the age constancy of AC/A according to the Hess- Gullstrand theory presumes that accommodative convergence and convergence accommodation remained linked in a constant fashion to ciliary muscle contraction throughout life. However, other factors may influence the accommodation- convergence interactions. Schor and Tsuetaki have demonstrated that robust vergence adaptation and poor accommodative adaptation result in a raised AC/A ratio. Thus changes in the accommodation convergence interactions with age may be due to changes in adaptability of tonic accommodation and vergence or to an alteration in the relationship between ciliary muscle contraction and accommodative response. If changes in the adaptability of tonic accommodation and vergence do occur with age, the observed changes in the accommodative- vergence cross- links would be explained and the Hess-Gullstrand model of presbyopia may still hold. In this way, the possibility remains that the relationship between ciliary muscle contraction and accommodative response is unchanged with age. In summary, we have confirmed an increase in the AC/A ratio with age.

Measurements were made on a moderate sample size of subjects who had normal binocular vision. Experiments of this nature may be unable to differentiate between the various models of presbyopia unless other factors that could concurrently influence the accommodative-vergence interactions, such as the adaptability of tonic vergence and accommodation, are taken into account [1].

Conclusion

The AC/A ratio increases within a person between 20 to 40 years of age. This may be because increasing ciliary muscle contraction is required to produce a given change in accommodation

with increasing age or because of change in the adaptability of the tonic accommodation and vergence system with age [1].

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