Emmetropization

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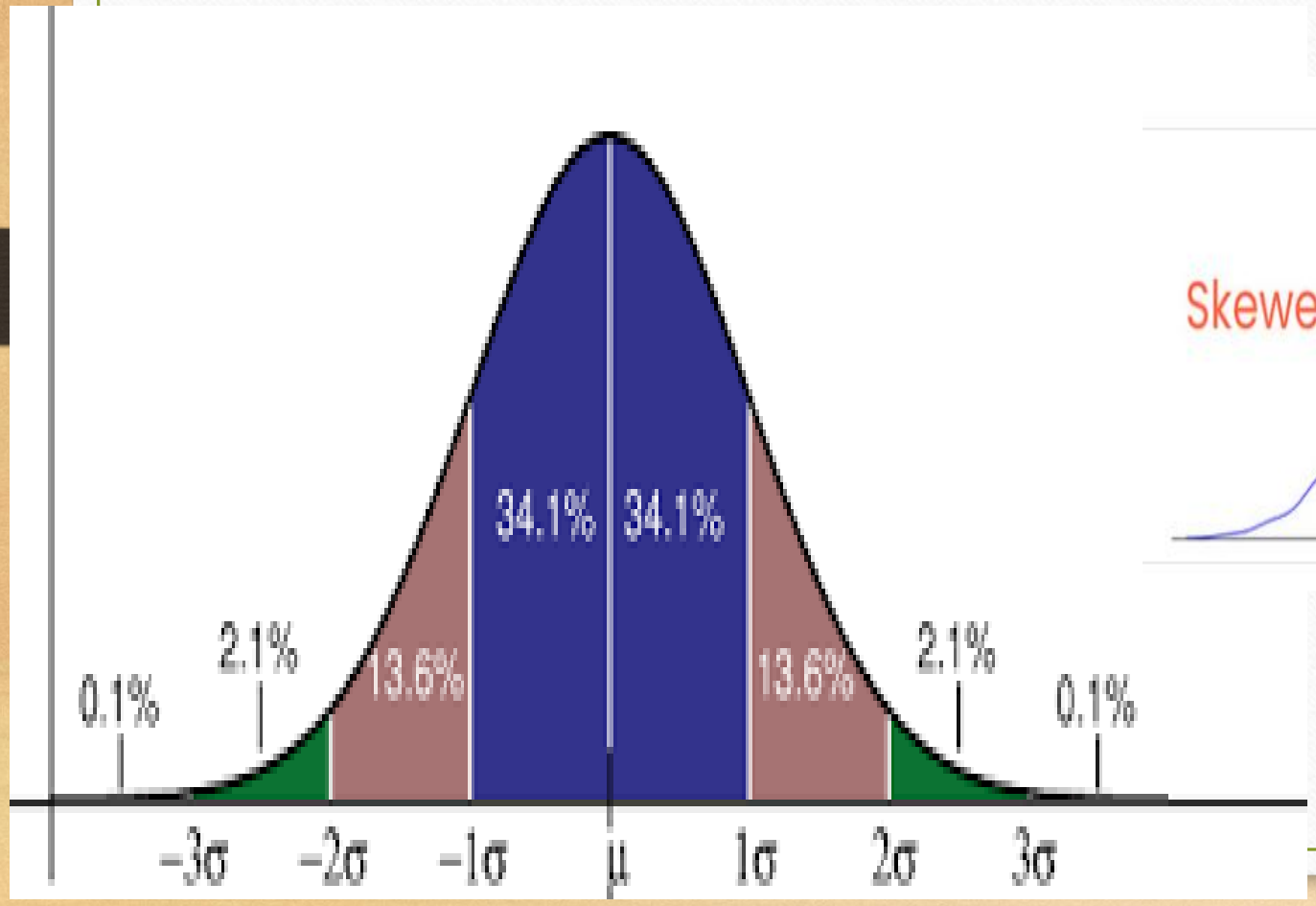
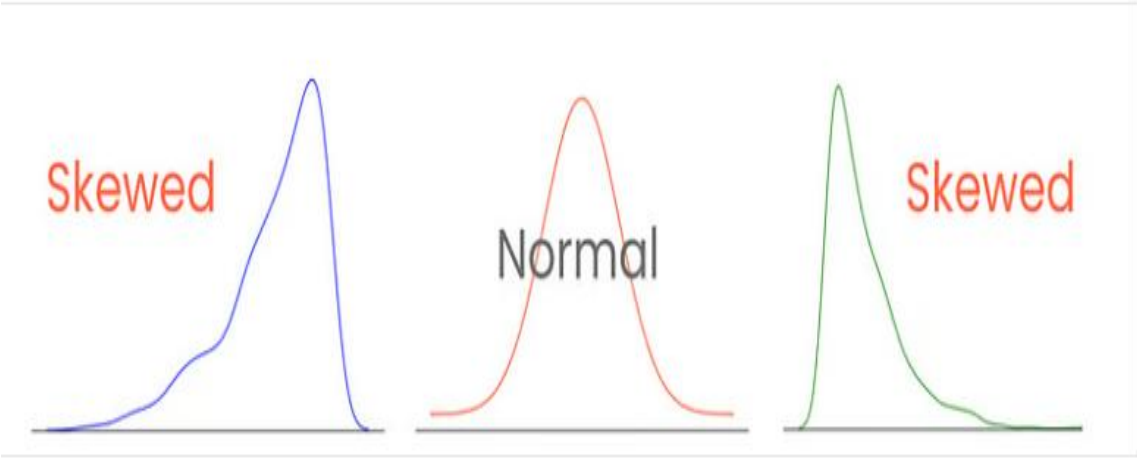
MUMS

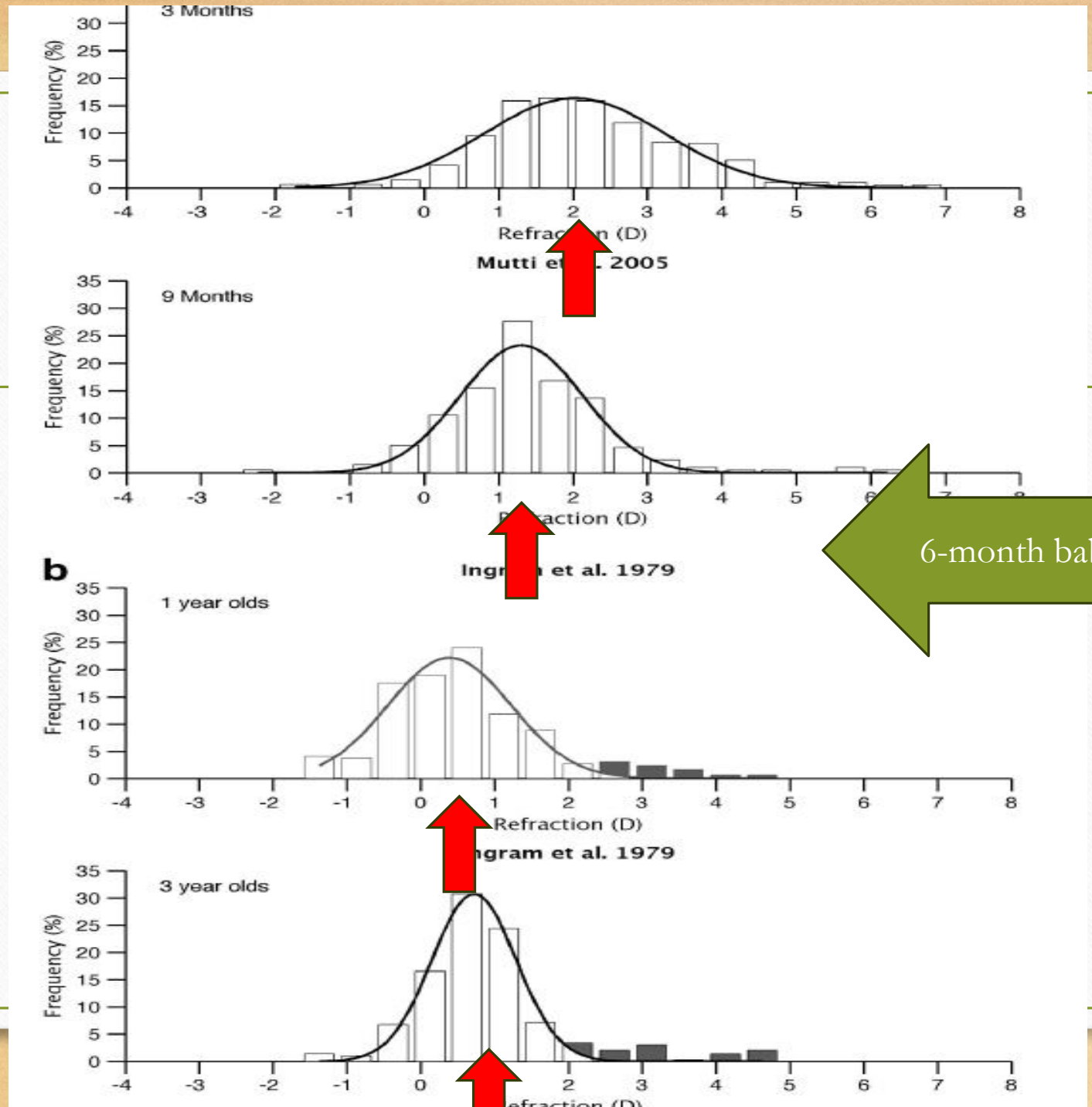
- At birth, the eyes of the majority of animals exhibit significant refractive errors and substantial individual differences in refractive error.

- These refractive errors diminish during early postnatal development as both eyes grow in a coordinated fashion toward what is presumed to be the ideal refractive state for a given species through a process called emmetropization.
- A hallmark of emmetropization is the systematic reduction over time of the intersubject differences in refractive error

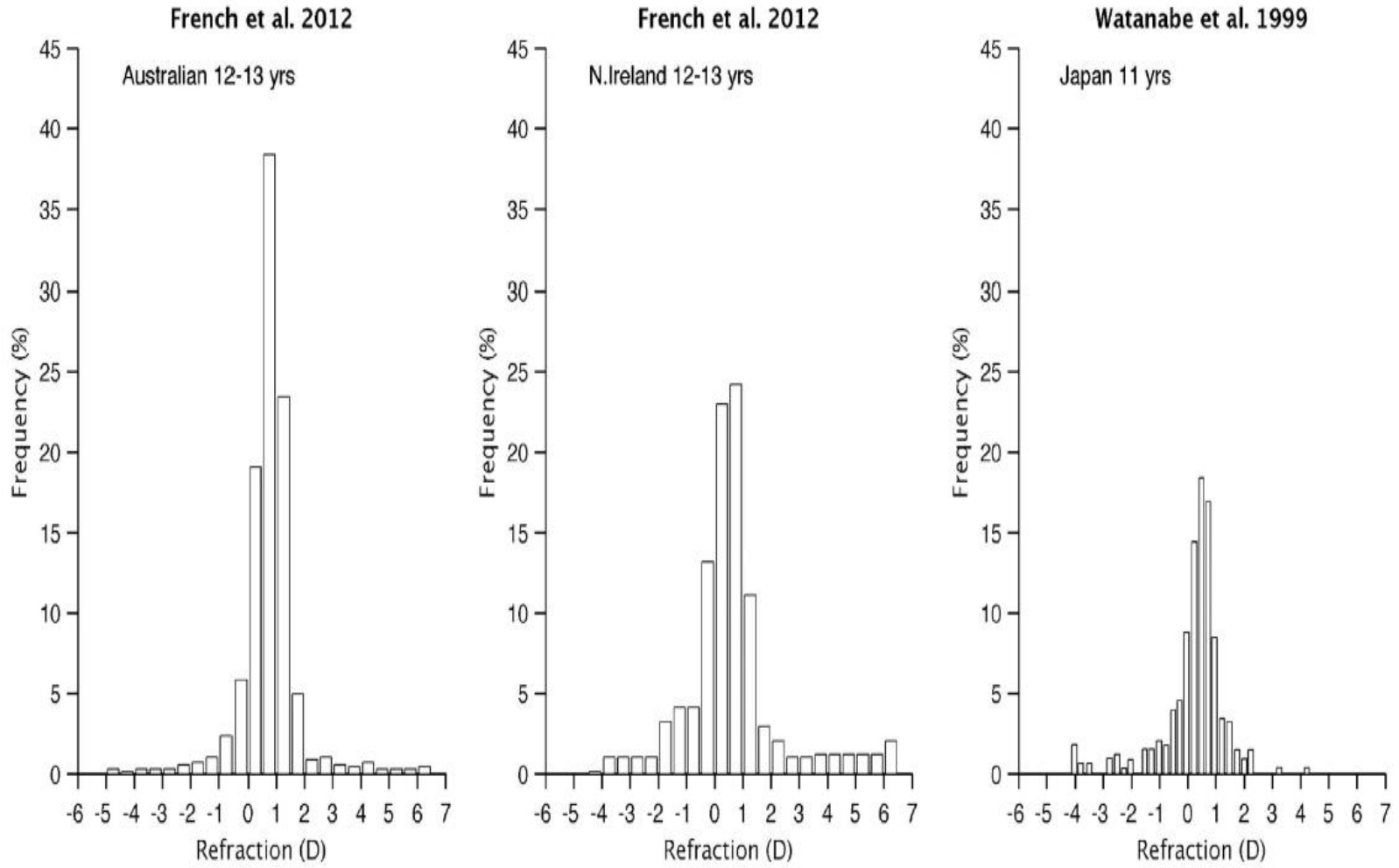
Normal Gaussian curve



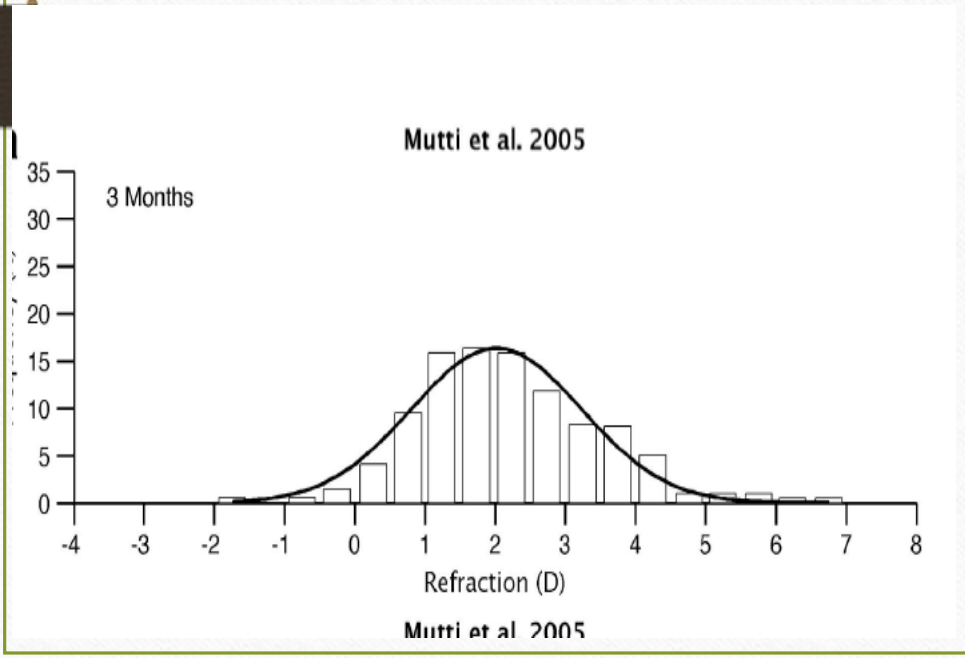


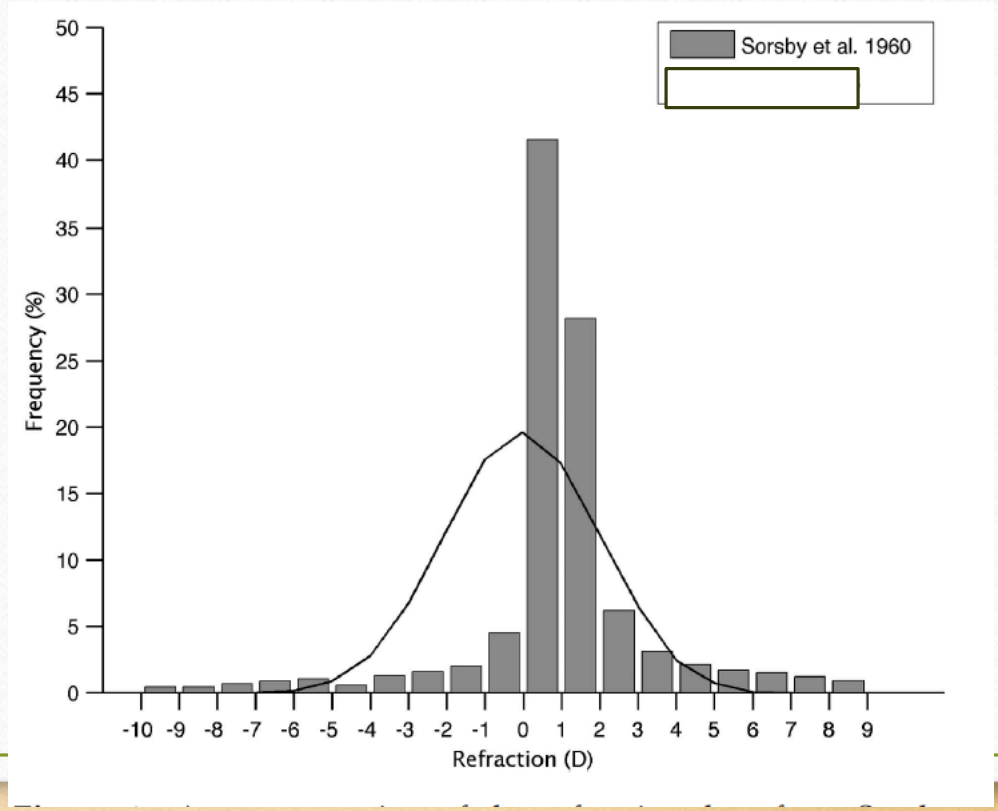


6-month baby infantile ET, FCR+2.00


French et al. 2012
Australian 12-13 yrs
French et al. 2012
N.Ireland 12-13 yrs
Watanabe et al. 1999
Japan 11 yrs
Frequency (%)
Refraction (D)
0
5
10
15
20
25
30
35
40
45
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7

- human refraction appears to be very different to many other biological variables such as height or intelligence test results, which typically display a normal (ie Gaussian) distribution
- Gaussian distribution of ametropia at birth mysteriously became **leptokurtic**, more concentrated about the mean, and birth hyperopia reducing to zero diopters with age





Pre Myopes

- The presence of +0.75 D or less of hyperopia at the age of 6 years indicates that myopia is likely to develop in the near future.

- It draws attention to the fact that these children need to be observed more closely

Passive control for emmetropization is ruled out

- Passive emmetropization proposals can be found in the literature, claiming that they are at least responsible **in part** for the developmental drift in refractions toward emmetropia

- They are generally based on the fact that **enlargement of the eye and its axial length** with growth is accompanied by a reduction in the power of the dioptric system in proportion to the increasing axial length

visually guided emmetropization

- Human infant emmetropisation reflects the optically guided growth mechanisms .
- Keeping in view the nature of visually guided emmetropisation, conditions that prevent clear vision from birth are associated with a lack of emmetropization and a broad range of refractions.
- The refraction in such children is shifted towards a myopic mean.
- In contrast, visual deficits that are not congenital but develop in the first 3 years are associated with hyperopic errors

Age of completion of emmetropization is controversy

- The bulk of emmetropisation occurs in early childhood and is largely complete **by age 6**.
- Emmetropization is active during the early years of life, since the non-Gaussian leptokurtic distribution of refractive errors, as observed by Sorsby in the young adult, is established in 6–8 year-olds.
- The commonest refractive error at age 6 is hyperopia with both anisometropia and myopia being far less common at this age.

Modern definition of emmetropization

- Medina “the controlling process that regulates the refraction of the human eye to achieve optimal visual acuity over the years”. 1987
- This definition has no time limitation, and is free from the restriction that emmetropization seeks emmetropia.
- The set point for each individual is referred Rs .
- Emmetropization is a homeostatic or feedback process since it regulates the refraction of the eye.

Medina Emphasizes on the effect of lenses!!

- if refraction is altered artificially, such as by the use of lenses, emmetropization will be misguided.

- In other words, emmetropization may direct an eye to become myopic or hyperopic instead of emmetropic because a corrective lens has been placed over that eye.

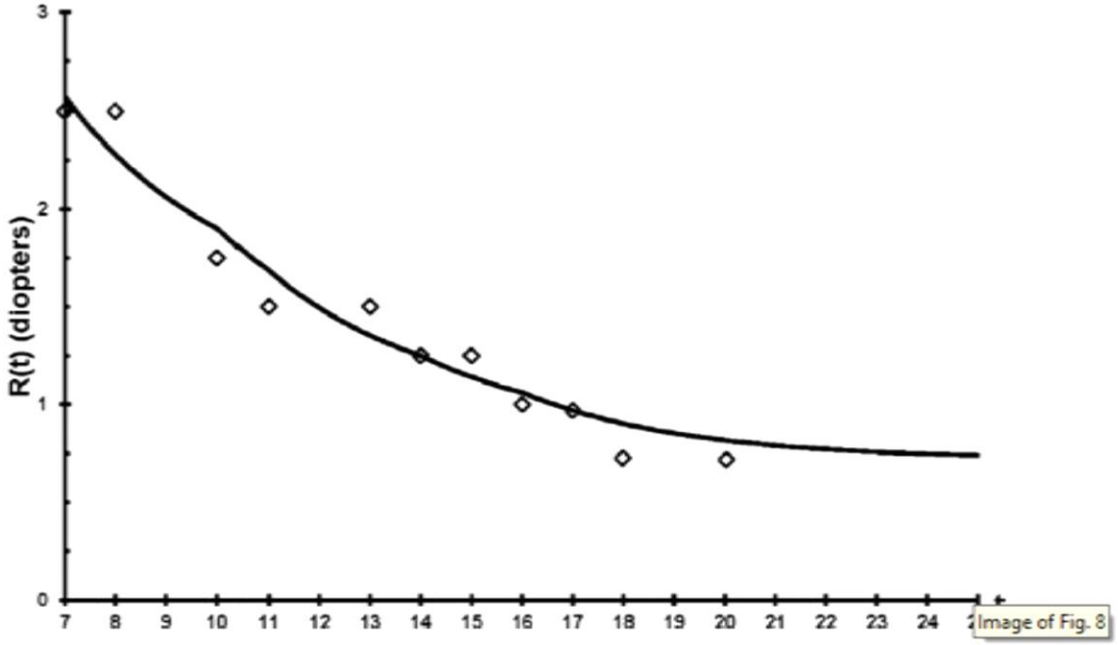


Fig. 8 – Effect of a plus lens before myopia develops. Actual refractive development (diamonds, spherical equivalent) of a child's eye whose hyperopia was corrected by 50% from age (t) 7–17 years and prediction of Feedback Theory if such correction were maintained indefinitely (R(t), continuous trace). Drawn from the author's data.

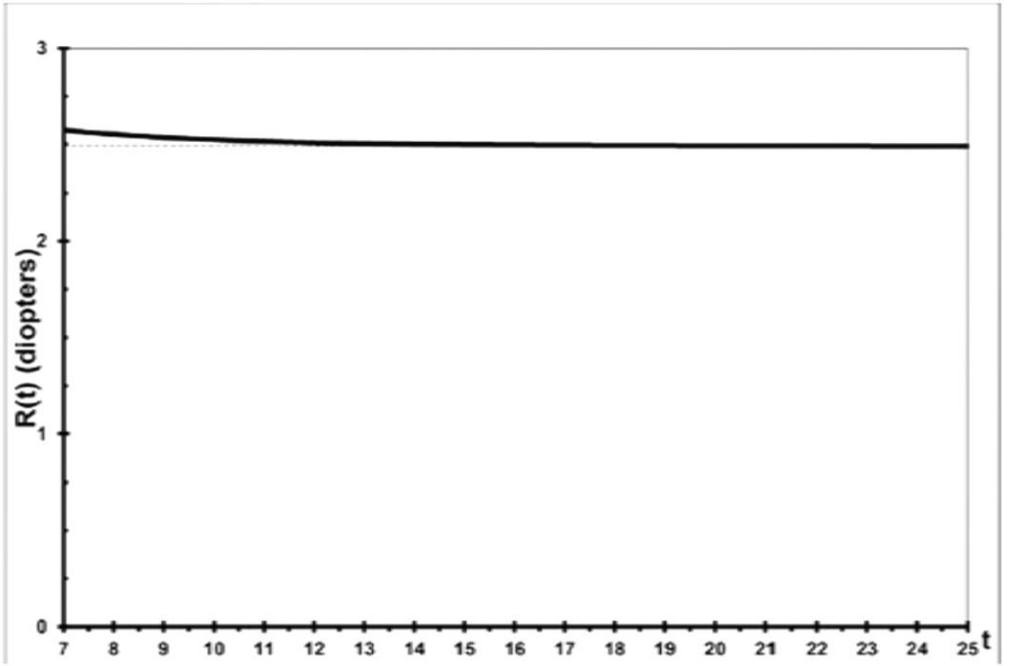


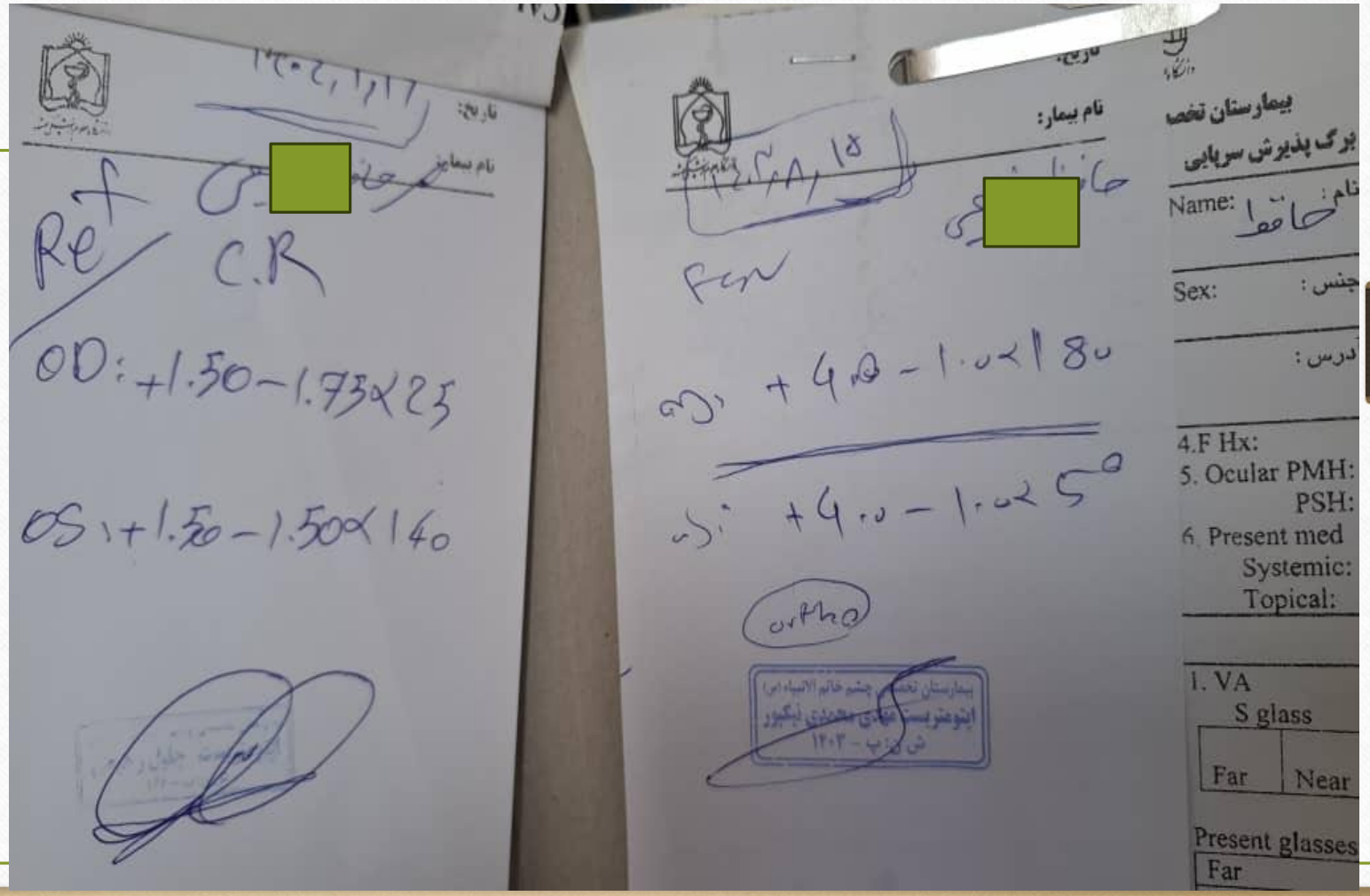
Fig. 9 – Prediction of Feedback Theory if the same child's hyperopia had been fully corrected.

tions of the Feedback Theory. According to the Theory, full

period of fast emmetropization : from 3 to 12 months

- Mutti and colleagues showed that the:
  - in a predominantly white sample
  - average cycloplegic spherical equivalent decreases:
    - from 2.16 D at 3 months to 1.36 D at 9 months


ATHLETICS


Ref
C.R
OD: +1.50 -1.75 x 25
OS: +1.50 -1.50 x 140
نام بیمار:
Fcn
+4.00 -1.00 x 180
+4.00 -1.00 x 5
ortho
بیمارستان تخصصی چشم خاتم الانبیاء (ص)
اپتومتریست
بیمارستان تخصصی
برگ پذیرش سرپایی
Name:
Sex: جنس :
آدرس :
4.F Hx:
5. Ocular PMH:
PSH:
6. Present med
Systemic:
Topical:
1. VA
S glass
Far
Near
Present glasses
Far

natural history of refractive error in 3 to 6 year-olds

natural history of refractive error in 3 to 6 year-olds

- less change during this period of life
- **slow movement** of the refractive error towards emmetropia
  - smallest standard deviation of the population's spherical equivalent refraction at 6 years:
    - mean is 0.70 to 1.0

Rate of Emmetropization

- rate of emmetropisation is generally proportional to the initial error

  - emmetropia or with a low amount of hyperopia : little change
  - higher ametropia :generally greater and faster change

Approximately 5% of infants between 6 months and 9 months of age have greater than 3 D of hyperopia

- Myopic neonates reduce their myopia and become emmetropes or hyperopes **by age 3**
- Investigators have identified faster rates of emmetropization among infants with greater initial RE
- We found that eyes with hyperopia or astigmatism emmetropized to a greater degree than eyes with myopia, and the greatest degree of emmetropization occurred among eyes with high astigmatism,
- followed by those with moderate astigmatism, moderate hyperopia, and high hyperopia, in that order.

Emmetropization during Early Childhood

Refractive error (RE) in infants is expected to decrease over time, a process known as emmetropization. The degree, timing, and rate of emmetropization have been hypothesized to be affected by infant age and initial RE. Investigators have identified faster rates of emmetropization among infants with greater initial RE.[1,2] The American Academy of Ophthalmology (AAO) recommends glasses prescription for defined ranges of RE at specific ages,

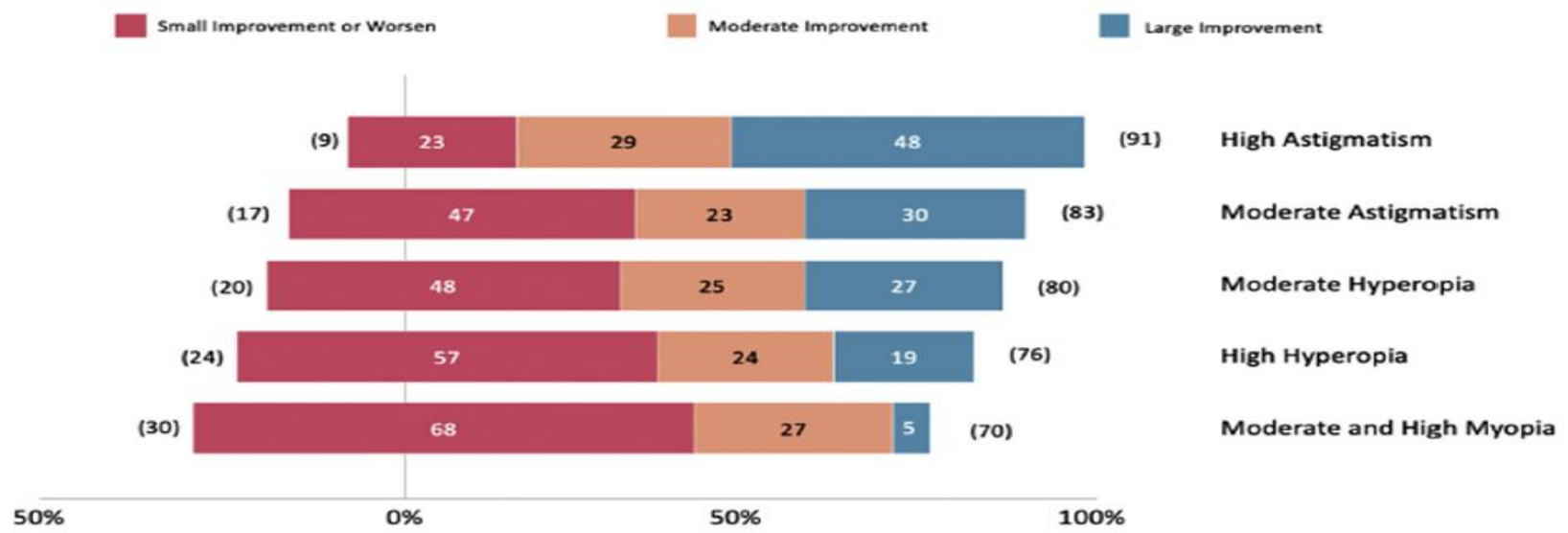
	Moderate Hyperopia +3.50 to +5.75D (N=147 eyes)	High Hyperopia +6.00D and above (N=21 eyes)	Combined Hyperopia +3.50D and above (N=168 eyes)
Initial SE			
Mean (SD)	4.4 (0.7)	6.5 (0.5)	4.6 (1.0)

B: initial myopic spherical equivalent of -2.00D and above.

	Moderate Myopia -2.00 to -4.75D (N=30 eyes)	High Myopia -5.00D and above (N=10 eyes)	Combined Myopia -2.00D and above (N=40 eyes)
Initial SE			

C: initial astigmatism of +1.50D cylinder and above.

	Moderate Astigmatism +1.50 to +2.75D (N=166 eyes)	High Astigmatism +3.00D and above (N=35 eyes)	Combined Astigmatism +1.50D and above (N=201 eyes)



To the left of 0 indicates percentage of eyes in each group with worsening refractive error, to the right of 0 indicates percentage of eyes with improving refractive error

High Astigmatism:
- Large improvement: 2 or more D of improvement
- Moderate improvement: 1 to less than 2 D of improvement
- Small improvement/worsen: less than 1 D of improvement or worsen

Moderate Astigmatism:
- Large improvement: 1.5 or more D of improvement
- Moderate improvement: 0.75 to less than 1.5 D of improvement
- Small improvement/worsen: less than 0.75 D of improvement or worsen

Moderate Hyperopia:
- Large improvement: 2 or more D of improvement
- Moderate improvement: 1 to less than 2 D of improvement
- Small improvement/worsen: less than 1 D of improvement or worsen

High Hyperopia:
- Large improvement: 3 or more D of improvement
- Moderate improvement: 1.25 to less than 3D of improvement
- Small improvement/worsen: 1 D or less of improvement or worsen

Moderate myopia
- Large improvement: 3 or more D of improvement
- Moderate improvement: 1 to 2.75 D of improvement
- Small improvement/worsen: less than 1D of improvement or worsen

High Myopia:

Astigmatism emmetropization

- There is also a higher prevalence of astigmatism at birth:
  - astigmatism 1.00 D or more :
    - 69 % of full-term newborns
  - studies with larger samples: 1.00 D or more of astigmatism
    - 8 to 30 % at 1 to 2 years
    - 4 to 24 % at 3 to 4 years
    - 2 to 17 % at 6 to 7 years
- in most populations there is a decrease in both the prevalence and degree of astigmatism in the first few years

Astigmatism type emmetropization

- higher prevalence of all types in infancy:
  - Significant WTR, ATR and oblique astigmatism are all more common in young children than adults
  - oblique astigmatism is the least common
- rate of decease of astigmatism is generally associated with the initial level:
  - higher amounts usually decreasing more rapidly

There is general agreement that: all types of astigmatism decrease

- infants losing two-thirds of their astigmatism between 9 - 21 months
  - most of this loss occurs in the first 18 - 24 months of life
- Some studies show that WTR decreases more rapidly
- others show that ATR is lost more rapidly, even switching to WTR in some cases

Ansiometropia Emmetropization

- Most studies have shown that **anisometropia is more common** in infants than adults
  - Varghese and colleagues: 30% of newborns
  - Zonis and Miller : 17 % of newborns

Ingram, Traynar and Walker and Abrahamsson, Fabian and Sjöstrand

- spherical anisometropia remains **more common in children** compared with adults

  up to at least four years of life

- spherical anisometropia of 1.00 D or more :
  - 7 to 11 % of 1 to 4 year old children
  - 0 to 5% of school children
- Some children gain anisometropia during this period, while others lose it

Transient Vs Persistent anisometropias :

- Transient anisometropias :
  - relatively lower level: 2.00 or 2.50 D or less
  - may not lead to amblyopia

- Persistent anisometropias:
  - Higher levels of anisometropia :**3.00 D or more**
  - are more likely to remain

clinical questions related to emmetropization

Will this particular child's refractive error emmetropise?

Effect of glasses on emmetropization

Benefit of prescribing spectacles as opposed to possible impediment to emmetropisation

- Will this particular child's refractive error emmetropise?

TABLE 2 GUIDELINES FOR REFRACTIVE CORRECTION IN INFANTS AND YOUNG CHILDREN

Condition	Refractive Errors (diopters)			
	Age <1 year	Age 1 to <2 years	Age 2 to <3 years	Age 3 to <4 years
Isoametropia (similar refractive error in both eyes)				
Myopia	5.00 or more	4.00 or more	3.00 or more	2.50 or more
Hyperopia (no manifest deviation)	6.00 or more	5.00 or more	4.50 or more	3.50 or more
Hyperopia with esotropia	1.50 or more	1.00 or more	1.00 or more	1.00 or more
Astigmatism	3.00 or more	2.50 or more	2.00 or more	1.50 or more
Anisometropia (without strabismus)*				
Myopia	4.00 or more	3.00 or more	3.00 or more	2.50 or more
Hyperopia	2.50 or more	2.00 or more	1.50 or more	1.50 or more
Astigmatism	2.50 or more	2.00 or more	2.00 or more	1.50 or more

Will this particular child's refractive error emmetropise?

- Although the majority of children will emmetropise, this is not true for all
- We would like to be able to predict those who will fully emmetropise:
  - as there is likely to be **no need to prescribe** spectacles in these cases
  - at least in the early years of life

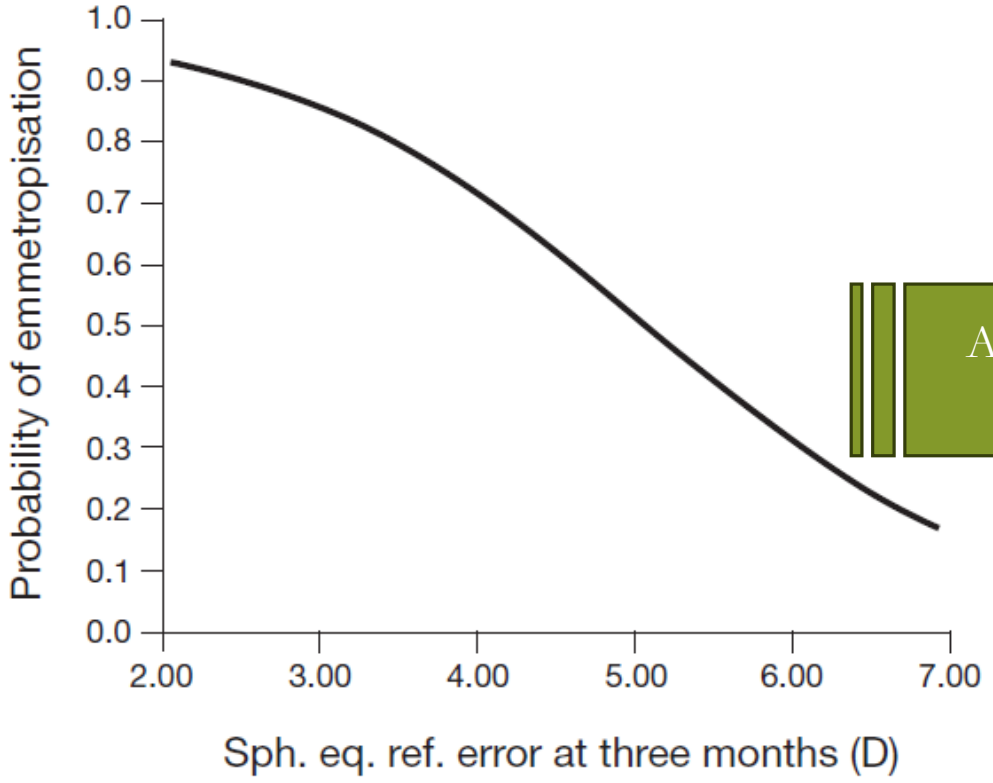
Will this particular child's refractive error emmetropise?

- Alternatively, those who will not emmetropise and who have a **high refractive error** might benefit from spectacle correction
- There is some evidence that children with **very high refractive errors** are less likely to emmetropise
- High hyperopia that not corrected with spectacles lead to amblyopia / esotropia

Will this particular child's refractive error emmetropise?

- Poor emmetropization prediction:
  - Higher cycloplegic refraction
  - Higher non-cycloplegic Mohindra retinoscopic refraction
  - ATR astigmatism
  - Strabismus

The probability of reaching 2.00 D by 18 months of age as a function of the level of cycloplegic spherical equivalent at three months of age



A 6-month old baby and FCR +5.5, ortho

Will this particular child's refractive error emmetropise? Ansiometropia Emmetropization

- if the anisometropia is 3.00 D or more at one year:
  - there is a high risk of it remaining and resulting in amblyopia
  - 30% increasing anisometropia over the following 9 years
  - 60% developing amblyopia
  - 90% retaining anisometropia of 1.00 D or more at the age of five years

Will this particular child's refractive error emmetropise?

- Children with lower amounts of anisometropia up to 2.00 D:
  - are more likely to lose it

to determine if a particular case of anisometropia is transient and therefore does not need intervention are:

- monitor a child!!!!!! over a period of four to six months
- visual acuities: if amblyopia is already present it requires treatment
- higher levels of anisometropia (3.00 D or more and particularly 5.00 D or more) are less likely to be transient

- Will prescribing glasses interfere with the normal process of emmetropisation?

Will prescribing glasses interfere with the normal process of emmetropisation?

- refractive correction will influence the development of refractive error
- Emmetropization will be misguided if refraction is altered artificially, such as by using lenses(feedback theory)

Will prescribing glasses interfere with the normal process of emmetropization?

- Emmetropization rate :
  - compliant spectacles wearers < non-compliant spectacle wearers or the controls
  - Atkinson et al showed that a partial spherical correction had no effect on emmetropization (1.00 D less than their full cycloplegic correction).
  - Partial h
    impair
    appear to

In myopia , there is no under correction

Accommodative esotropia

- Prescribing the full cycloplegic refraction initially will provide the best opportunity for restoring ocular alignment and maintaining good visual acuity and stereopsis.

- Once normal e… …tended period of time, ho… …many childre…

Factors such as the need to treat amblyopia or strabismus, or to optimize ocular alignment, outweigh the need to leave a stimulus for emmetropization.

Will this level of refractive error disrupt normal visual development or functional vision?

Will this level of refractive error disrupt normal visual development or functional vision?

- amblyopia and decreased steroacuity :
  - more than 1.00 D of spherical hyperopic anisometropia
  - more than 2.00 D of spherical myopic anisometropia
  - more than 1.50 D of Cylindrical anisometropia (either myopic or hyperopic)

Will this level of refractive error disrupt normal visual development or functional vision?

- visual system:
  - in the first year of life :
    - may not be very sensitive to uncorrected astigmatism
  - from one year onwards:
    - uncorrected astigmatism, particularly oblique astigmatism: meridional amblyopia

Anisometropia (without strabismus)*				
Myopia	4.00 or more	3.00 or more	3.00 or more	2.50 or more
Hyperopia	2.50 or more	2.00 or more	1.50 or more	1.50 or more
Astigmatism	2.50 or more	2.00 or more	2.00 or more	1.50 or more

case

- A 6-month-baby
- OD+1.5
- OS +3.50

Case :

- 5-year-old girl
- OD=+1.5 sphere, OS=+5.00 sphere
- What is your management?

Refractive therapy ”optical treatment”

- The correction of any underlying refractive error by prescribing glasses is the **first step** in the treatment of amblyopia
- Regardless of whether **the cause** of the amblyopia is anisometropia, strabismus, or both
- improvement in VA in the amblyopic eye is considerable at 4 to 12 weeks
- then reaches a plateau, after which it improves only slowly

Clinical examples of a failure of emmetropization

- Large congenital refractive errors do exist but are rare and often associated with genetic disorders.
- Examples of clearly genetic congenital refractive errors include the congenital and non-progressive myopia associated with Stickler's syndrome and Leber's amaurosis.
- In such cases there appears to be a strong genetic bias away from emmetropia and the large initial refractive errors remain largely unmodified by any emmetropisation mechanism.

- Visual deficits such as those associated with albinism and other causes of nystagmus are also associated with impaired emmetropisation and broad refractive distributions.

- Astigmatism is also greatly increased in albinism and one analysis suggests that the vertical refractive meridian, which is unaffected by the motion blur of horizontal nystagmus, may display some degree of emmetropisation.

Down’s syndrome

- A more dramatic failure of emmetropization can be observed in Down’s syndrome despite the good visual acuity usually observed in this condition.

- reveal the underlying pattern of genetically determined eye growth.