Optical Biometry - The Long and The Short of it

Debbie Jones FCOptom FAAO FBCLA
Clinical Professor – School of Optometry & Vision Science
Clinical Scientist - Centre for Ocular Research & Education

1

Financial Disclosures

- **Debbie Jones** has served as a consultant/speaker for:
  - CooperVision Inc
  - SightGlass Vision
  - Essilor
  - Alcon

This lecture is presented without bias and is not intended to endorse specific products or companies

2

Optical Biometry

WHAT – What is biometry
WHY – Why is biometry important
HOW – How do we measure AL
WHAT – What to do with the information

3

WHAT is Biometry

Measurement of the power of the cornea (keratometry) and the axial length (AL)

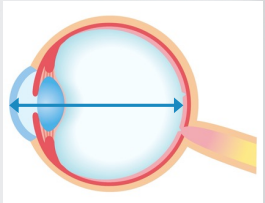
For myopia control purposes we focus on the Axial Length

4

WHAT is Axial Length (AL)

AL is measured from anterior cornea to retinal RPE & includes:
- anterior chamber depth
- lens thickness
- vitreous chamber depth

AL is the most significant contributor to refractive error



5

WHY – is biometry important?

6

WHY is Biometry important?

AL measurement provides the full story about myopia

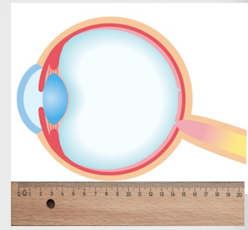
- 0.1mm = -0.25 change
- 1mm ≈ 2.25D

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

7

How long is an eye?

Typical axial length[1,2]:
Infancy 16.8mm
Adult 23.6mm
AL does change with age in non-myopes[3,4]
0.20 mm/year <age 8
0.10-0.15mm/year age 9-11



Myopic eyes grow about 0.2mm[5]

1. Gordon RA, Donzis PB. Refractive development of the human eye. Arch Ophthalmol. 1985;103(6):785-9
2. Atchison DA, Jones CE, Schmid KL, Pritchard N, Pope JM, Strugnell WE, Riley RA. Eye shape in emmetropia and myopia. Invest Ophthalmol Vis Sci. 2004 Oct 1;45(10):3380-6
3. Tideman JWL, et al. Axial length growth and the risk of developing myopia in European children. Acta Ophthalmol. 2018;96(3):301-9
4 . Zadnik K, Mutti DO, Mitchell GL, et al. Normal Eye Growth in Emmetropic Schoolchildren. Optom Vis Sci 2004;81:819-28
5. Chamberlain P, Peixoto-de-Matos SC, Logan NS, et al. A 3-Year Randomized Clinical Trial of Misight Lenses for Myopia Control. Optom Vis Sci 2019;96:556-67

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

8

Why do we measure AL?

The peak rate of axial elongation occurs in the 2 to 3 years before myopia onset[1]
- Essential to monitor change over time
- Good predictor of SERE change

1D ≈ 0.28mm increase age 6 to 7 [1,2]
0.32mm increase age12-13
0.40mm increase adults

1. Mutti, D.O., et al., *Refractive error, axial length, and relative peripheral refractive error before and after the onset of myopia.* Invest Ophthalmol Vis Sci, 2007. **48**(6): p. 2510-9.
2. Cruickshank FE, Logan NS. Optical 'dampening' of the refractive error to axial length ratio: implications for outcome measures in myopia control studies. *Ophthalmic Physiol Opt.* 2018;38(3):290–7.

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

9

Interpreting the science

Analysis of clinical trial results

Imperative good correlation between AL and ref error change
eg: Atom 2 study 0.01% Atropine 59% efficacy for SERE, -8% for AL.[1]

AL and SERE must be reported as primary outcome measures in clinical studies[2]

1. Chia *et al.*: Atropine for the treatment of childhood myopia: safety and efficacy of 0.5%, 0.1%, and 0.01% doses (Atropine for the Treatment of Myopia 2). Ophthalmology 2012; 119;2: 347-54.
2. Wolffsohn J, et IMI – Clinical Myopia Control Trials and Instrumentation Report. *Invest. Ophthalmol. Vis. Sci.* 2019;60(3):M132-M160

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

10

Every dioptre matters aka every mm matters!

Each additional dioptre is associated with an increased risk of:

Myopic maculopathy	58%
Retinal detachment	30%
Posterior subcapsular cataract	21%
Open Angle Glaucoma	20%

Bullimore MA, Ritchey ER, Shah S, Leveziel N, Bourne R, Flitcroft DI: The risks and benefits of myopia control. Ophthalmology 2021: https://doi.org/10.1016/j.ophtha.2021.04.032

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

11

Effect of axial length on risk of visual impairment

Risk of Visual Impairment

	Odds ratio	
Axial Length (mm)	Age <60 years	≥ 60 years
<24	1 (reference)	1 (reference)
24 to <26	0.95	0.65
26 to <28	2.01	3.07
28 to <30	11.01	9.69
≥ 30	24.69	93.62

Significant risk with AL >26mm

Tideman JW et al Association of Axial Length with Risk of Uncorrectable Visual Impairment for Europeans with myopia JAMA Ophthalmol 2016;34:1355-63

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

12

Biometry

HOW – do we measure AL

13

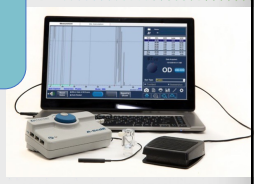
HOW do we measure axial length?

Two basic methods
- Ultrasound
- Optical based methods

14

Ultrasound

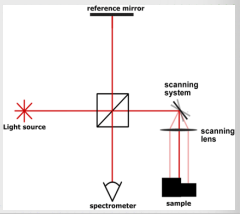
A-scan ultrasound (Amplitude scan)
Outdated and superseded
- Topical anesthesia required
- Accuracy approximately 0.10mm[1]
- Test-retest repeatability ±0.2 to ±0.3mm[2]
- Variability 0.062 ± 0.043[3]



15

Optical Biometers

1. Partial Coherence Interferometry (PCI)
2. Optical Low-Coherence Reflectometry (OLCR)
3. Swept -source Optical Coherence Tomography (OCT)



16

Comparing Biometers

Ultrasound	Accuracy 0.1mm Repeatability ±0.2 to ±0.3mm[1]	Various
PCI	Accuracy 0.01-0.02mm Repeatability ±0.04mm[2]	IOL Master 500 (*Carl Zeiss Meditec*) Pentacam AXL (*Oculus*) Optical Biometer AL-Scan (*Nidek*) Myopia Master (*Oculus*)
OLCR	Accuracy 0.01-0.02mm Repeatability ±0.035mm[3] (*Lenstar 900*)	Lenstar LS 900 (*Haag-Streit*) Aladdin and Aladdin-M/Myah (*Topcon*) Myopia Expert 700 (Essilor)
SS-OCT	Accuracy 0.01-0.02mm Repeatability ±0.024mm[4] (*IOL master 700*)	IOLMaster 700 (*Carl Zeiss Meditec*) OA-2000 (*Tomey*) ARGOS Advanced Optical Biometer (*MOVU*) Revo FC (*Optopol Technology Ltd*)

17

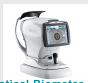
Partial Coherence Interferometry (PCI)

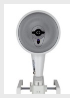
Ultrasound	Accuracy 0.1mm Repeatability ±0.2 to ±0.3mm[1]	Various
PCI	Accuracy 0.01-0.02mm Repeatability ±0.04mm[2]	IOL Master 500 (*Carl Zeiss Meditec*) Pentacam AXL (*Oculus*) Optical Biometer AL-Scan (*Nidek*) Myopia Master (*Oculus*)
OLCR	Accuracy 0.01-0.02mm Repeatability ±0.035mm[3] (*Lenstar 900*)	Lenstar LS 900 (*Haag-Streit*) Aladdin and Aladdin-M/Myah (*Topcon*) Myopia Expert 700 (Essilor)
SS-OCT	Accuracy 0.01-0.02mm Repeatability ±0.024mm[4] (*IOL master 700*)	IOLMaster 700 (*Carl Zeiss Meditec*) OA-2000 (*Tomey*) ARGOS Advanced Optical Biometer (*MOVU*) Revo FC (*Optopol Technology Ltd*)

18

Partial Coherence Interferometry (PCI)

- Overestimation of AL if there is active accommodation[1]
- Accuracy (0.01-0.02mm)[2,3]
- Repeatability ±0.04mm[4]


Optical Biometer AL-Scan,(Nidek)


Pentacam AXL (Oculus)


Myopia Master (Oculus)


IOL Master 500 (Zeiss)

1. Atchison DA, Smith G. Possible errors in determining axial length changes during accommodation with the IOLMaster. *Optom Vis Sci.* 2004; 81: 283–286.
2. Santodomingo-Rubido J, Mallen EA, Gilmartin B, Wolffsohn JS. A new non-contact optical device for ocular biometry. *Br J Ophthalmol.* 2002; 86: 458–462.
3. Drexler W, Findl O, Menapace R, et al. Partial coherence interferometry: a novel approach to biometry in cataract surgery. *Am J Ophthalmol.* 1998; 126: 524–534.
4. Hussin HM et al. Reliability and validity of the partial coherence interferometry for measurement of ocular axial length in children. Eye (Lond) 2006;20:1021-4

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

19

Optical Low-Coherence Reflectometry (OLCR)

Ultrasound	Accuracy 0.1mm Repeatability ±0.2 to ±0.3mm[1]	Various
PCI	Accuracy 0.01-0.02mm Repeatability ±0.04mm[2]	IOL Master 500 (*Carl Zeiss Meditec*) Pentacam AXL (*Oculus*) Optical Biometer AL-Scan (*Nidek*) Myopia Master (*Oculus*)
OLCR	**Accuracy 0.01-0.02mm** **Repeatability ±0.035mm[3]** **(*Lenstar 900*)**	**Lenstar LS 900 (*Haag-Streit*)** **Aladdin and Aladdin-M/Myah (*Topcon*)** **Myopia Expert 700 (Essilor)**
SS-OCT	Accuracy 0.01-0.02mm Repeatability ±0.024mm[4] (*IOL master 700*)	IOLMaster 700 (*Carl Zeiss Meditec*) OA-2000 (*Tomey*) ARGOS Advanced Optical Biometer (*MOVU*) Revo FC (*Optopol Technology Ltd*)

1. Wolffsohn, J et al. IMI - Clinical Myopia Control Trials and Instrumentation Report. Invest Ophthalmol Vis Sci. 2019;60(3): M132-M160.
2. Hussin HM et al. Reliability and validity of the partial coherence interferometry for measurement of ocular axial length in children. Eye (Lond) 2006;20:1021-4.
3. Dogan M, Elgin U, Sen E, Tekin K, Yilmazbas P. Comparison of anterior segment parameters and axial lengths of myopic, emmetropic, and hyperopic children. *Int Ophthalmol.* 2019;39(2):335–40.
4. Yang JY, Kim HK, Kim SS. Axial length measurements: Comparison of a new swept-source optical coherence tomography–based biometer and partial coherence interferometry in myopia. *J Cataract Refract Surg.* 2017;43(3):328–32.

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

20

Optical Low-Coherence Reflectometry (OLCR)

- Repeatability Lenstar 900 = 0.035mm[1]
- Confirmed good correlation of OLCR with AL measures from IOL Master 500 (PCI)[2,3]


Lenstar 900 (Haag-Streit)


MYAH (Topcon)


Myopia Expert 700 (Essilor)

1. Dogan M, Elgin U, Sen E, Tekin K, Yilmazbas P. Comparison of anterior segment parameters and axial lengths of myopic, emmetropic, and hyperopic children. *Int Ophthalmol.* 2019;39(2):335–40.
2. Mandal, P et al. Validity and repeatability of the Aladdin ocular biometer. Br J Ophthalmol, 2014:98(2), 256-258
3. Huang, J. et al. Meta-analysis of optical low-coherence reflectometry versus partial coherence interferometry biometry. Sci Rep, 2017;7, 43414

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

21

Swept-source Optical Coherence Tomography (SS-OCT)

Ultrasound	Accuracy 0.1mm Repeatability ±0.2 to ±0.3mm[1]	Various
PCI	Accuracy 0.01-0.02mm Repeatability ±0.04mm[2]	IOL Master 500 (*Carl Zeiss Meditec*) Pentacam AXL (*Oculus*) Optical Biometer AL-Scan (*Nidek*) Myopia Master (*Oculus*)
OLCR	Accuracy 0.01-0.02mm Repeatability ±0.035mm[3] (*Lenstar 900*)	Lenstar LS 900 (*Haag-Streit*) Aladdin and Aladdin-M/Myah (*Topcon*) Myopia Expert 700 (Essilor)
SS-OCT	**Accuracy 0.01-0.02mm** **Repeatability ±0.024mm[4]** **(*IOL master 700*)**	**IOLMaster 700 (*Carl Zeiss Meditec*)** **OA-2000 (*Tomey*)** **ARGOS Advanced Optical Biometer (*MOVU*)** **Revo FC (*Optopol Technology Ltd*)**

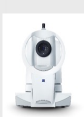
1. Wolffsohn, J et al. IMI - Clinical Myopia Control Trials and Instrumentation Report. Invest Ophthalmol Vis Sci. 2019;60(3): M132-M160.
2. Hussin HM et al. Reliability and validity of the partial coherence interferometry for measurement of ocular axial length in children. Eye (Lond) 2006;20:1021-4.
3. Dogan M, Elgin U, Sen E, Tekin K, Yilmazbas P. Comparison of anterior segment parameters and axial lengths of myopic, emmetropic, and hyperopic children. *Int Ophthalmol.* 2019;39(2):335–40.
4. Yang JY, Kim HK, Kim SS. Axial length measurements: Comparison of a new swept-source optical coherence tomography–based biometer and partial coherence interferometry in myopia. *J Cataract Refract Surg.* 2017;43(3):328–32.

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

22

Swept-source Optical Coherence Tomography (SS-OCT)

- Repeatability IOL Master 700 0.024mm[1]


IOL Master 700 (Zeiss)


OA-2000 (Tomey)


ARGOS (MOVU)


Revo FC (Optopol Tech)

1. Yang JY, Kim HK, Kim SS. Axial length measurements: Comparison of a new swept-source optical coherence tomography–based biometer and partial coherence interferometry in myopia. *J Cataract Refract Surg.* 2017;43(3):328–32.

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

23

Multifunction instruments

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

24

Multifunction instruments - advantages

- Streamline patient journey
- Space saving
- Time saving
- Cost effective
- Patient education
- Assessment of risks
- Outcome prediction
- Additional capabilities (not related to myopia)
- eg. CL fit, Dry eye assessment

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

25

Multifunction instruments - software

- Comparison with age related normative data for AL
- Prediction of efficacy of treatment choice, demonstration of potential outcomes
- Indication of risk (AL in relation to SERE, near work, parental myopia etc)
- Progression reports
- Take home reports

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

26

Multifunction instruments

PCI	Accuracy 0.01-0.02mm Repeatability ±0.04mm[2]	IOL Master 500 (*Carl Zeiss Meditec*) Pentacam AXL (*Oculus*) Optical Biometer AL-Scan (*Nidek*) Myopia Master (*Oculus*)
OLCR	Accuracy 0.01-0.02mm Repeatability ±0.035mm[3] (*Lenstar 900*)	Lenstar LS 900 (*Haag-Streit*) Aladdin and Aladdin-M/Myah (*Topcon*) Myopia Expert 700 (Essilor)
SS-OCT	Accuracy 0.01-0.02mm Repeatability ±0.024mm[4] (*IOL master 700*)	IOLMaster 700 (*Carl Zeiss Meditec*) OA-2000 (*Tomey*) ARGOS Advanced Optical Biometer (*MOVU*) Revo FC (*Optopol Technology Ltd*)

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

27

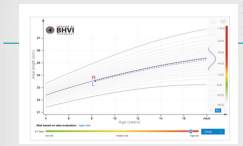
Myopia Master (Oculus)

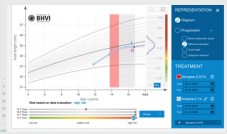
Myopia Master

- AL
- Refraction
- Keratometry
- Compares data with age related norms (Caucasian/Asian eyes)
- Progression over time
- Indication of potential efficacy of treatment
- Risk profile
- Reports for parents

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

28






CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

29

MYAH (Topcon)

MYAH

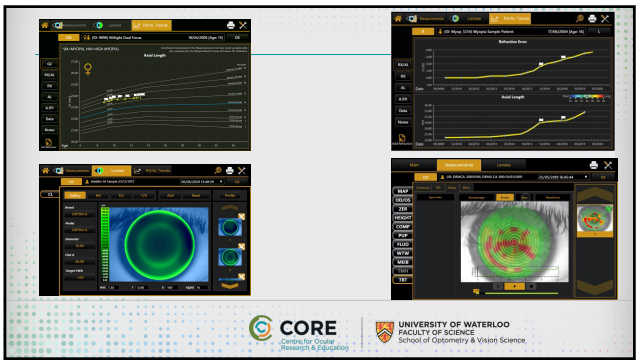
- AL
- Pupillometry
- Topography
- Compares data with age related norms (European)
- Progression over time
- Reports for parents
- CL fitting support
- Dry eye assessment

MYAH, Topcon

Aladdin M - same hardware
- No reference growth curves
- No dry eye module

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

30



31

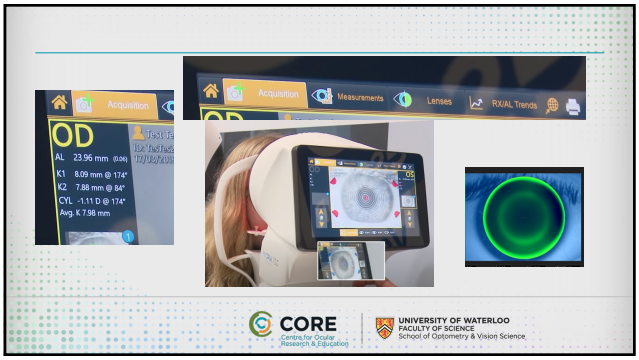
Myopia Expert 700 (Essilor)

Myopia Expert 700

- AL
- Pupillometry
- Topography
- Keratometry
- Compares data with age related norms (Asian/ Euro)
- Progression over time
- Reports for parents
- CL fitting support

Myopia Expert 700, Essilor

32



33

REVO FC (Optopol Technology Ltd)

REVO FC

- AL
- Topography
- Fundus Camera
- OCT Imaging

REVO FC,
Optopol Technology Ltd

34

Instrument Software "add-ons"

Eye Suite software

- Compares data with age related norms (Asian/ Euro)
- Import refraction data
- Monitor Change
- Patient reports

LENSTAR MYOPIA, Haag Streit
(Lenstar 900 + Eye Suite)

35

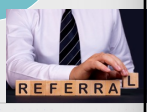
No instrument yet?

Consider referral to a colleague (cataract surgeon)

Fee for service (patient pays them or you pay them)

Annual measurement

Better to ask someone else to provide the service than NOT have AL



36

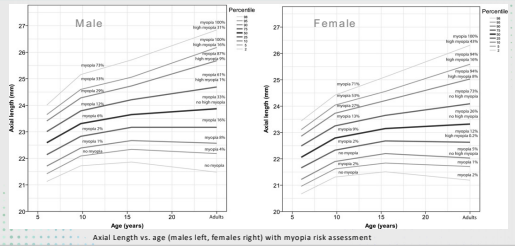
WHAT do with the information

Compare to normative data

Compare change over time

37

Normative data - European



Axial Length vs. age (males left, females right) with myopia risk assessment

Tideman JWL et al. Axial length growth and the risk of developing myopia in European children. Acta Ophthalmol. 2018;96(3):301-9.

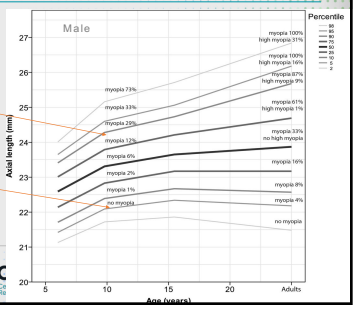
38

Clinical application –Case #1

10-year-old male patient

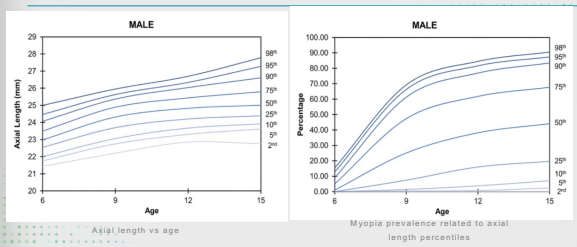
Scenario 1 - Axial Length 24.2mm
- 29% chance of being myopic now
- 87% chance of being myopic as an adult
- 9% chance of having high myopia

Scenario 2 – AL 22.0mm
- No myopia
- 4% risk of being myopia as an adult
- 0% risk of having high myopia



39

Normative data - Asian



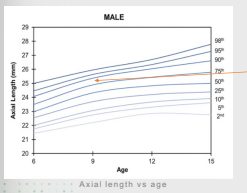
Axial length vs age

Myopia prevalence related to axial length percentiles

Sánz Diez P, et al. Growth curves of myopia-related parameters to clinically monitor the refractive development in Chinese schoolchildren. Graefes Arch Clin Exp Ophthalmol. 2019 May;257(5):1045-1053.

40

Clinical application – Case #2



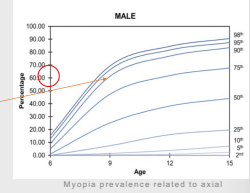
Axial length vs age

9-year-old patient

axial length 24mm

90th percentile

60% prevalence of myopia

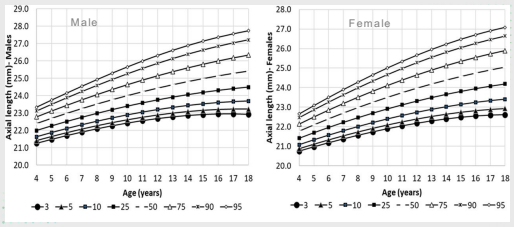


Myopia prevalence related to axial length percentiles

Sánz Diez P, et al. Growth curves of myopia-related parameters to clinically monitor the refractive development in Chinese schoolchildren. Graefes Arch Clin Exp Ophthalmol. 2019 May;257(5):1045-1053.

41

Normative data - Asian



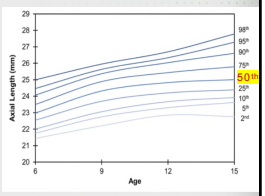
He, X., et al., *Normative data and percentile curves for axial length and axial length/corneal curvature in Chinese children and adolescents aged 4-18 years.* Br J Ophthalmol, 2015.

42

Clinical application - Percentiles

Below 50th percentile AL for age, less likely to become myopic

Above 50th percentile more likely to become myopic



CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

43

Clinical application – Assess risk

Assess risk of myopia based on AL and AL growth rate[1]

AL of 23.07mm for 6–7-year-old indicative of future myopia development

AL change of 0.74mm across a 3-year time period suggests future myopia development

Compare patient in chair to normative data (consider ethnicity)

1. McCullough, S., et al., *Axial growth and refractive change in white European children and young adults: predictive factors for myopia.* Sci Rep, 2020. 10(1): p. 15151.

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

44

Biometry: The long and the short of it!

Axial length values change over time and can help predict the onset of myopia

Biometry is an essential part of the myopia puzzle

- Provides information on the success of the myopia management treatment modailty

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

45

Further information

46

CORE Centre for Ocular Research & Education | UNIVERSITY OF WATERLOO FACULTY OF SCIENCE School of Optometry & Vision Science

47