

The Central Corneal Light Reflex Ratio from Photographs Derived from a Digital Camera in Young Adults

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Objective: To determine the normal range of Central Corneal Light Reflex Ratio (CCLRR) from photographs of young adults.
Material and Method: A digital camera equipped with a telephoto lens with a flash attachment placed directly above the lens was used to obtain corneal light reflex photographs of 104 subjects, first with the subject fixating on the lens of the camera at a distance of 43 centimeters, and then while looking past the camera to a wall at a distance of 5.4 meters. Digital images were displayed using Adobe Photoshop at a magnification of 1,200%. The CCLRR was the ratio of the sum of distances between the inner margin of cornea and the central corneal light reflex of each eye to the sum of horizontal corneal diameter of each eye. Measurements were made by three technicians on all subjects, and repeated on a 16% (n = 17) subsample.

Results: Mean ratios (standard deviation - SD) from near/distance measurements were 0.468 (0.012)/0.452 (0.019). Limits of the normal range, with 95% certainty, were 0.448 and 0.488 for near measurements and 0.419 and 0.484 for distance measurements. Lower and upper indeterminate zones were 0.440-0.447 and 0.489-0.497 for near measurements and 0.406-0.418 and 0.485-0.497 for distance measurements. More extreme values can be considered as abnormal. The reproducibility and repeatability of the test was good.

Conclusion: This method is easy to perform and has potential for use in strabismus screening by paramedical personnel.

Keywords: Central corneal light reflex, Photographs, Screening, Strabismus

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Nowadays, ocular misalignment (strabismus) screening is very important especially in young people, since strabismus is one of the causes of amblyopia in children. The screening needs specialists to work in the ophthalmic field and remains a big problem in Thailand owing to the lack of qualified personnel.

Several methods are available for assessing ocular alignment. They can be grouped into four basic types, light reflex test, cover test, dissimilar image test, and dissimilar target test⁽¹⁾. The Hirschberg test is one of the light reflex tests. The test is based on the reduced schematic eye, which assumes that human eyes are symmetrical so when a light is shone into the eyes, a point of light will appear on the corneal surface – the so-called corneal light reflex (CLR). The CLR will be centered in the eye without strabismus or latent

strabismus and it will be decentered in the strabismic eyes.

Although the direct estimation of the corneal light reflex test is less satisfactory when compared to the prism and cover test⁽²⁾, which is considered as a standard method for a strabismus test, it is nevertheless often used in clinical practice, both at the bedside and with people with poor fixation or lack of cooperation.

The present study was aimed to focus on the measurement of CLR from photographs derived from a digital camera to determine the range of central corneal light reflex ratio (CCLRR) in young adults with healthy eyes. The interpretation of the present study is based on the principle of the Hirschberg test as described above.

Material and Method

The research proposal was approved by the Ethics Committee of the Faculty of Medicine, Prince of Songkla University. The present study enrolled 104 students, aged from 16 to 20 with healthy eyes, who had just passed the entrance examination at the Faculty of Medicine, Prince of Songkla University. All

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subjects provided an informed consent to participate. Each subject had to pass a medical history taking and complete eye examination that included an orthoptic examination and an autorefractometer measurement by ophthalmologists and orthoptist in Songklanagarind Hospital, and had to have a visual acuity greater than 20/40 as well as no manifest strabismus (tropia). The data were collected on January 13 and 14, and March 3, 2010.

Corneal light reflex photographs were obtained by using a Fuji FinePix S2000HD digital camera equipped with F/3.5-5.4 telephoto lens, set at a focal length of 28 mm and F/3.5, with the flash located above the lens. The photograph resolution was set as 2,048 x 1,536 pixels. The camera was positioned on a tripod with the lens at the same level as the subject's eyes and operated by a one camera technician. The subject placed his or her head on a head/chin rest and fixated first on the lens of the camera at a distance of 43 centimeters (near), and then looked past the camera to a wall located at a distance of 5.4 meters (distant). One photograph at each focusing distance was taken.

Digital images were transferred to a desktop computer with a liquid crystal display (LCD) screen of dimensions 12 x 14 inches set at a resolution of 1024 x 768 pixels, and displayed using Adobe Photoshop version CS at a magnification of 1,200%. The positions of the corneal flash reflection and of the inner and outer margins of each cornea were recorded using the cursor and scale provided in the software. From these positions, the horizontal distances of the light reflection from inner corneal margins (A and C) and the horizontal diameter of each cornea (B and D) were measured and the CCLRR calculated as $(A + C) / (B + D)$, as demonstrated Fig. 1. All measurements were made independently by three observers. Each observer measured and calculated all parameters on every photograph taken from 104 subjects, and a 16% (n = 17) subsample of the photographs was re-measured and the ratio recalculated. Bland-Altman plots were used to assess the interobserver and intraobserver agreement in estimation of the CCLRR.

The reference range for CCLRR was defined as the mean \pm 2 standard deviation (SD). However, because of sampling variability, these values, for both the mean and the standard deviation are subject to uncertainty. Therefore, within the overall range of possible values, two limits were calculated within which values could be reliably considered "normal", two more extreme limits beyond which values could be reliably considered "abnormal", with the zone between

these two limits in each direction being designated "indeterminate" zones. The calculations of these limiting values were made following the principle presented by Leslie and Greenberg⁽³⁾.

The number of subjects included in the present study also followed the directions of Leslie and Greenberg⁽³⁾, who demonstrated that a sample size of at least 100 was needed for the indeterminate zone around a mean \pm 2 SD to range from the mean \pm 1.66 SD to \pm 2.34SD with 95% confidence. Thus, each indeterminate zone would be sufficiently narrow to be of practical use. In this circumstance, the indeterminate zones would have a width of only about one fifth of the "normal" range.

Results

One hundred four subjects, including 51 females and 53 males, fitting the inclusion criteria were enrolled. The mean age was 18.35 years (range of 17.17 to 19.84 years). The alternate prism and cover test at near/distance revealed orthophoria in 44 (42.3%)/99 (95.2%), exophoria in 59 (56.7%)/4 (3.8%) and esophoria in one (1%)/one (1%). The means (\pm SD) of the refraction value were -2.32 diopters (-4.76 ± 0.46) on the right eye, and -2.32 diopters (-4.34 ± 0.30) on the left eye.

Using data of the first observer, the mean CCLRR (\pm SD) from near/distance measurements was estimated to be 0.468 (0.012)/0.452 (0.019). The limits of the normal range, with 95% certainty, were 0.448 and 0.488 for near measurements and 0.419 and 0.484 for distance measurements. The lower and upper indeterminate zones were 0.440 to 0.447, and 0.489 to

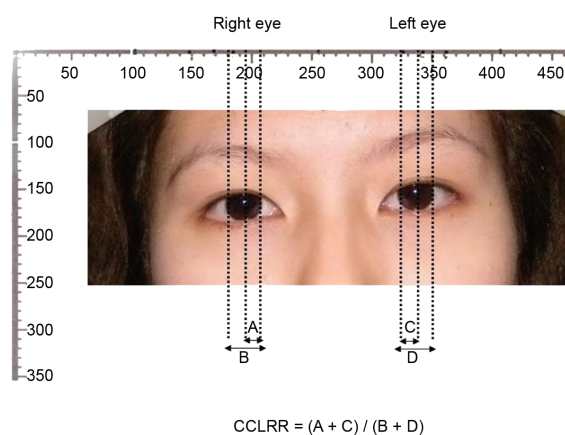


Fig. 1 Measurements as made from the digital image, displayed on the computer screen

0.497 for near measurements and 0.406 to 0.418 and 0.485 to 0.497 for distance measurements. More extreme values can be considered as abnormal (Table 1).

The parameters estimated by each of the three observers from the full sample of 104 subjects are shown in Table 2. Limits of the normal range of CCLRR differed by no more than 0.001 for the near measurements and by no more than 0.003 for the distance measurements. Discrepancies between members of each of the three pairs of observers in the estimates of CCLRR for each subject were shown by Bland-Altman plots in Fig. 2. Ninety-five percent of the discrepancies in the CCLRR (mean \pm 2 SD) were within approximately \pm 0.01 both in near and in distance measurements.

Intraobserver discrepancies in the estimated CCLRR of each of the subset of 17 subjects from measurements of the three observers were shown by Bland-Altman plots in Fig. 3. For each observer, 95% of the discrepancies in CCLRR (mean \pm 2 SD) were within less than \pm 0.01 for near and approximately \pm 0.01 for distance measurements.

Table 1. Estimated parameters of CCLRR at near and distance measurement by first observer in 104 subjects

Parameter	Near	Distance
Mean	0.468	0.452
Standard deviation	0.012	0.019
Normal range	0.448 to 0.488	0.419 to 0.484
Indeterminate zones	0.440 to 0.447 0.489 to 0.497	0.406 to 0.418 0.485 to 0.497
Abnormal range	<0.440 >0.497	<0.40 >0.497

Discussion

The present study presents the range of central corneal light reflex ratio (CCLRR), which is the ratio of the summed distances from the inner corneal margins to the corneal light reflex of the right and the left eyes (A and C), and the horizontal diameter of the right and left eyes (B and D), as estimated using digital photography with the camera flash as the light source. The ratio is based on the Hirschberg's assumption that the visual axis passes through the center of the cornea so that when a light is shone into the eyes, the corneal reflection will be centered in the cornea of the fixating eye but will be decentered in the deviating eye.

Taking into account the imprecision of determination on a sample taken from the population of subjects and considering the mean \pm 2 SD as the range of normal, which means the subjects have either orthophoria or latent strabismus, a reference range for CCLRR was identified as 0.448 to 0.488 for near and 0.419 to 0.484 for distance measurement. Values of < 0.440 or > 0.497 for near and < 0.406 or > 0.497 for distance measurement should be considered abnormal which means the subjects possibly have manifest strabismus, while intermediate values can be considered to be indeterminate. For strabismus screening, subjects with values that fall into the indeterminate or abnormal range should be sent to ophthalmologists to look for the ocular misalignment.

Previous studies have demonstrated the Hirschberg's coefficient to vary between 7 and 10.5 degrees/millimeter of corneal light reflex deviation from the visual axis, depending on specific design of the study⁽⁴⁻¹²⁾. The authors consider that the use of the ratio from both eyes may be superior to the methods used in previous studies because the ratio is not affected by magnification of the images, variation of

Table 2. Estimated parameters of CCLRR at near and distance measurement by three observers

Parameter	Near			Distance		
	Observer 1	Observer 2	Observer 3	Observer 1	Observer 2	Observer 3
Mean	0.468	0.468	0.467	0.452	0.451	0.450
SD	0.012	0.012	0.012	0.019	0.019	0.020
Normal	0.448 to 0.488	0.448 to 0.488	0.447 to 0.487	0.419 to 0.484	0.419 to 0.483	0.416 to 0.483
Indeterminate	0.440 to 0.447 0.489 to 0.497	0.440 to 0.447 0.489 to 0.496	0.439 to 0.446 0.488 to 0.495	0.406 to 0.418 0.485 to 0.497	0.407 to 0.418 0.484 to 0.495	0.403 to 0.415 0.484 to 0.497
Abnormal	<0.440 >0.497	<0.440 >0.496	<0.439 >0.495	<0.406 >0.497	<0.407 >0.495	<0.403 >0.497

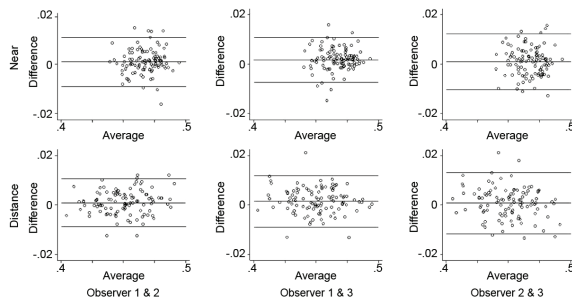


Fig. 2 Estimated Bland-Altman plots of CCLRR to show discrepancies between each member of pairs of observers' data of near, and distance measurements of 104 subjects. The horizontal lines denote the mean, and mean \pm 2 SD of the discrepancies

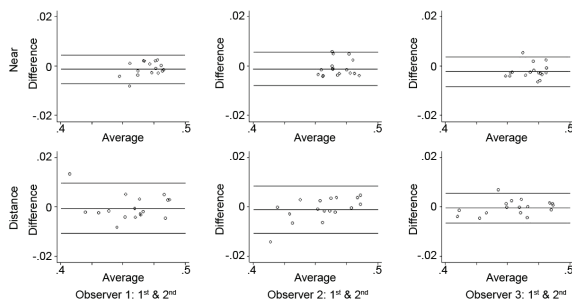


Fig. 3 Estimated Bland-Altman plots of CCLRR to show discrepancies between first and second measurement sessions of near, and distance measurements made by each observer on a random subset of 17 subjects. The horizontal lines denote the mean, and mean \pm 2 SD of the discrepancies

the corneal diameter or slight deviations in the position of the subject's face.

Both interobserver reproducibility and intraobserver repeatability are good. Ninety-five percent of interobserver discrepancies in CCLRR in both near and distance measurements were within ± 0.01 , which is approximately 15% of the total range of near, and 10% of the total range of distance measurements. Intraobserver discrepancies were less. Except close to the limits of the normal range, such discrepancies are unlikely to be clinically significant. These properties suggest that the method could readily be adopted as a standard strabismus screening tool by technical staff without extensive training.

The strength of the present study lies in the acknowledgement of uncertainty when inferring population parameters from sample measurements, so

that an indeterminate range around the theoretical normal limits of mean \pm 2 SD was estimated, according to the concept of Leslie and Greenberg⁽³⁾. The concept may yield a more practical screening test, as a sharp distinction between "normal" and "abnormal" is not realistic.

Nevertheless, the present study was conducted only in young subjects with healthy eyes, although those with latent strabismus were not excluded. It is recommended that further study be carried out in a wider range of subjects and settings and that the method be further validated using strabismic patients.

Conclusion

The determination of CCLRR from photographs derived from a digital camera is easy to perform. Determination of the normal range of CCLRR by this method indicates that it has potential for use in strabismus screening. As the method can be performed by paramedical personnel, it is especially suitable for use in the community.

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Potential conflicts of interest

None.

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อัตราส่วนแสงสะท้อนกระจกตาจุดกลางจากภาพถ่ายกล้องดิจิทัลในคนวัยหนุ่มสาว

สุอัมภา ดวงสังข์, สุภาภรณ์ เต็งไตรสรณ์

วัตถุประสงค์: เพื่อหาช่วงปกติของอัตราส่วนแสงสะท้อนกระจกตาจุดกลางจากภาพถ่ายคนวัยหนุ่มสาว

วัสดุและวิธีการ: กล้องดิจิทัลพร้อมเลนส์โทรภาพชนิดแฟลชด้านตรงติดเหนือเลนส์ เพื่อรับภาพถ่ายแสงสะท้อนกระจกตาส่วนกลาง ตัวอย่างจำนวน 104 คน ขึ้นแรกกำหนดตัวอย่างมองผ่านเลนส์กล้องที่ระยะทาง 43 เซนติเมตร ครั้นแล้วให้มองผ่านกล้องไปยังผนังที่ระยะทาง 5.4 เมตร ภาพดิจิทัลแสดงโดย โปรแกรมโฟโต้ชอป อะโดบี ขยาย 1,200 เปอร์เซ็นต์ อัตราส่วนแสงสะท้อนกระจกตาจุดกลางเป็นอัตราส่วนของผลรวมระยะทางระหว่างขอบกระจกตา ด้านใน และแสงสะท้อนกระจกตาจุดกลางของแต่ละตา ต่อผลรวมของเส้นผ่าศูนย์กลางกระจกตาแนวนอนของแต่ละตา ทุกตัวอย่างวัดโดยนักเทคนิค 3 คน และทำซ้ำร้อยละ 16 ของตัวอย่าง (17 คน)

ผลการศึกษา: อัตราเฉลี่ย (ค่าเบี่ยงเบนมาตรฐาน) จากการวัดใกล้/ไกล เท่ากับ 0.468 (0.012)/0.452 (0.019) ขอบเขตของช่วงปกติกับความแน่นอน 95 เปอร์เซ็นต์ คือ 0.448 และ 0.488 สำหรับการวัดระยะใกล้ และ 0.419 และ 0.484 สำหรับการวัดระยะไกล ค่าที่ไม่แน่นอนช่วงบนและช่วงล่างเท่ากับ 0.440 ถึง 0.447 และ 0.489 ถึง 0.497 สำหรับการวัดระยะใกล้ และ 0.406 ถึง 0.418 และ 0.485 ถึง 0.497 สำหรับการวัดระยะไกล ค่าที่เกินสุดโด่งพิจารณาว่าเป็นความผิดปกติ การทดสอบอีกครั้งและทำซ้ำถูกต้องดี

สรุป: วิธีการนี้ง่ายในการทำและมีศักยภาพต่อประโยชน์ในการตรวจคัดกรองภาวะตาเขในโดยบุคลากรที่ไม่ใช่แพทย์
