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The development of norms of pediatric interpupillary distance

Abstract

Interpupillary distances (PDs) were measured on 220 Caucasian children, newborn to six years of age, at fixation distances of 3 m and 40 em. A photographic method was used to determine the distance between the corneal light reflexes provided by the camera flash. The subjects were divided into six groups based on age. The average PDs (mm) for each age group were: Group 1 (newborn-11 months): NA/40.5; Group 2 (12-23 months): 46.5/43.0; Group 3 (24-35 months): 47.5/43.5; Group 4 (36-47 months): 49.5/46.0; Group 5 (48-59 months): 51.0/46.5; Group 6 (60-71 months): 51.0/46.5; far/near respectively.

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Paul Kohl

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The Development of Norms of
Pediatric Interpupillary
Distance

by

MARY M. ZEISE
DEBRA L. WILLIAMS

A thesis submitted to the faculty of the
College of Optometry
Pacific University
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Advisors:
Paul Kohl, OD
Thomas Samson, OD

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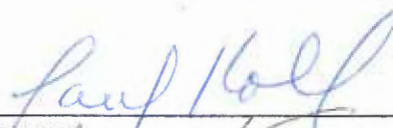
by

MARY M. ZEISE
DEBRA L. WILLIAMS

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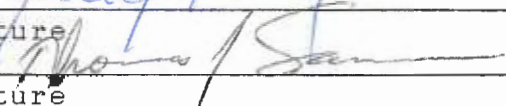
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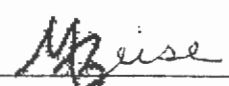
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Mary M. Zeise

Mary M. Zeise was born and raised in a small town in rural Minnesota. She attended Concordia College in Moorhead, Minnesota from 1985-1989, earning majors in biology and psychology and a minor in chemistry. Then she moved to Forest Grove, OR to attend Pacific University College of Optometry for 1989-1993. Following graduation in May of 1993, she will be an optometric resident at the University of Alabama at Birmingham in the Family Practice program. Following the one year residency, she will plan to return to Minnesota and open a private practice.

Debra L. Williams

Debra L. Williams was born and raised in the midwest. She completed a BS degree in Biology with minors in Math and Chemistry from Friends University, Wichita, Kansas in 1987. She and her husband, Jeff Williams, moved to the northwest to attend Optometry school at Pacific University College of Optometry in Forest Grove, OR. After graduation, they plan to join an existing practice in the midwest and practice behavioral pediatric optometry.

ABSTRACT

Interpupillary distances (PDs) were measured on 220 Caucasian children, newborn to six years of age, at fixation distances of 3 m and 40 cm. A photographic method was used to determine the distance between the corneal light reflexes provided by the camera flash. The subjects were divided into six groups based on age. The average PDs (mm) for each age group were: Group 1 (newborn-11 months): NA/40.5; Group 2 (12-23 months): 46.5/43.0; Group 3 (24-35 months): 47.5/43.5; Group 4 (36-47 months): 49.5/46.0; Group 5 (48-59 months): 51.0/46.5; Group 6 (60-71 months): 51.0/46.5; far/near respectively.

INTRODUCTION

There are published norms of adult interpupillary distances (PDs) for both males and females and also for different races. As previously reported, the average far PD (mm) for an adult Caucasian male is 63.50, adult Caucasian female is 60.50, adult African American is 70.00, and adult Oriental is 61.00 (1). No norms have been published for direct interpupillary distance measurement for children under the age of five years. Pryor measured the two intercanthal distances and used these dimensions in a specific formula to derive an objective interpupillary distance (2). The lack of hard data in this area may be due to the difficulty in obtaining PDs using the traditional methods with this age group.

Interpupillary distance is determined by using either the optic axes or the visual axes. The optic axis is a line that passes through the centers of curvature of all the optical elements (i.e., corneal and lens surfaces) (3). The visual axis is a line connecting the fovea to the point of fixation and passing through the nodal point of the eye (3). When the eyes fixate a point at optical infinity, so that the visual axes are parallel, the optic axes are divergent. The angle between the optic axis and visual axis is called angle alpha. The distance between the optic axes is on the average 0.95 mm larger than the distance between the visual axes as shown by McCormick and McGill (4). Since it is usually desirable to place the optical centers of ophthalmic lenses in alignment with the visual axis of each eye (5), the interpupillary distance using the visual axes is more appropriate for clinical measurement of PDs. [See Illustration 1]

Because the positions of the visual axes can be determined by the corneal reflexes, the measurement of a patient's PD can be made by using a penlight with a PD rule or using a device such as the corneal reflex pupillometer (CRP). Both methods require the patient to maintain steady fixation for an extended period of time. This steady fixation period can be a difficult task for young children.

In this study, in order to assess PD in the early pediatric population, a photographic technique was chosen which required only brief fixation by the subject, and

provided a permanent record that could be evaluated repeatedly. This method, developed by Bogren, Franti, and Wilmarth, "was found to have the highest degree of repeatability with a coefficient of variation of 0.215%. This translates into an accuracy of 0.1 mm with a range of 0.0 mm to 0.4 mm" (6).

The purpose of this study is to determine the mean PDs for children, newborn to 6 years of age, at fixation distances of 3 m and 40 cm. This relatively unresearched area is important for two reasons: 1) to quantify pediatric PDs to serve as developmental norms and 2) to aid in the development of size suitable diagnostic and therapeutic instrumentation such as pupillometers and spectacles for use with the earlier pediatric population.

SUBJECTS

220 subjects (108 males, 112 females) between newborn and six years of age were divided into six age groups:

- Group 1: newborn to 11 months
- Group 2: 12 months to 23 months
- Group 3: 24 months to 35 months
- Group 4: 36 months to 47 months
- Group 5: 48 months to 59 months
- Group 6: 60 months to 71 months

The sample population was 92% Caucasian and 8% mixed Caucasian including children of Asian, African American,

Indian, and Hispanic descent. The children were volunteer participants from local Head Start programs, private daycare facilities and children of the students and faculty of Pacific University College of Optometry. Any child who had an obvious strabismic deviation or facial abnormality was excluded from the study. Information regarding each child's gender, race, date of birth and expected due date was obtained from the parent. The age of the subject was determined from the child's actual delivery date rather than from their expected due date.

METHODS

Four frontal face photographs were taken of each subject, two at 3 m (using a 210 mm lens) and two at 40 cm (using a 50 mm lens). Each child was seated in a chair or upon an adult's lap and instructed to look at a specific target mounted on the front of the camera. Noise makers, puppets and other attention attracters were utilized to maintain fixation. A standard camera flash was used to produce the corneal light reflexes. For each photograph, a PD rule was held above the child's eyes by an assistant to serve as a reference measurement device. At least two photographs were taken of each subject at both fixation distances, with the exception of Group 1 subjects. These subjects were only photographed at 40 cm due to poor fixation control at 3 m.

Thirty-five millimeter color slides were developed and

then projected on a screen. The distance between the reflexes was compared to the PD rule in each picture to determine the patient's PD. Both investigators measured each slide, thus producing four measurements for each of the subjects at each distance (with the exception of Group 1 which was only photographed at 40 cm). All measurements were recorded to the nearest 0.5 mm. The four near measurements were then averaged to determine the mean near PD for each subject. The same procedure was followed with the far measurements.

To validate the photographic method, a pilot study was performed using 15 Caucasian adult subjects. The PDs of the subjects were measured with a CRP at the 2 m and the 40 cm settings and compared to the measurements found using the photographic method. The same camera set up was used as in the pediatric study with the exception of the distant photograph which was taken at 2 m for comparison with the 2 m setting on the CRP. The results of this pilot study found that the average pupillometer PDs (mm) were 61.23/58.00 and the average photographic PDs (mm) were 61.52/58.50; far/near respectively. A Pearson r correlation test was used to compare the pupillometer and the photographic results for both 2 m and 40 cm. A strong correlation was found at both distances with $r = 0.992$ at 2 m and $r = 0.964$ at 40 cm. [See Figures 1 and 2] A paired t-test, with 95% level of significance was also performed for both fixation distances. While there was no statistically significant difference

between the methods at 40 cm ($p = 0.1316$), there was a statistically significant difference at 2 m ($p = 0.0292$). Although a statistical difference was found, the measured difference between the methods at 2 m of the means was only 0.29 mm. Since 0.5 mm is the smallest measurable value commonly used in the clinical setting, the difference between the methods is not clinically significant.

RESULTS

Descriptive statistics for the mean PDs (mm) at far and near for this sample population are summarized for each age group in Table 1.

For Group 1, newborn to 11 months, the average far PD was not obtained due to poor fixation ability. The average near PD was 40.5 mm (SD = 2.44, range = 35.00 mm - 45.00 mm). There were 38 subjects (16 females; 22 males) with an average age of 5.5 months.

For Group 2, 12-23 months, the average far PD was 46.5 mm (SD = 2.19, range = 42.88 mm - 52.25 mm). The average near PD was 43.0 mm (SD = 2.13, range = 38.75 mm - 47.38 mm). The difference between near and far PD was 3.5 mm. There were 41 subjects (18 females; 23 males) with an average age of 18.0 months.

For Group 3, 24-35 months, the average far PD was 47.5 mm (SD = 2.44, range = 41.13 mm - 52.88 mm). The average near PD was 43.5 mm (SD = 2.43, range = 38.88 mm - 48.00 mm). The difference between near and far PD was 4.0 mm.

There were 36 subjects (21 females; 15 males) with an average age of 28.5 months.

For Group 4, 36-47 months, the average far PD was 49.5 mm (SD = 2.18, range = 46.38 mm - 53.63 mm). The average near PD was 46.0 mm (SD = 2.21, range = 43.00 mm - 50.75 mm). The difference between near and far was 3.5 mm. There were 31 subjects (15 females; 16 males) with an average age of 41.5 months.

For Group 5, 48-59 months, the average far PD was 51.0 mm (SD = 2.45, range = 46.25 mm - 55.25 mm). The average near PD was 46.5 mm (SD = 2.86, range = 40.75 mm - 52.63 mm). The difference between near and far was 4.5 mm. There were 42 subjects (24 females; 18 males) with an average age of 53.5 months.

For Group 6, 60-71 months, the average far PD was 51.0 mm (SD = 2.77, range = 45.38 mm - 56.25 mm). The average near PD was 46.5 mm (SD = 2.69, range = 41.17 mm - 52.75 mm). The difference between near and far was 4.5 mm. There were 32 subjects (18 females; 14 males) with an average age of 64.5 months.

The results were analyzed as a function of age and gender. The mean PD by age increased linearly both at near and at far until age 4 to 5 years. The average near PD of Group 1 was 40.5 mm, while the average near PD of Groups 5 and 6 were 46.5 mm. The average far PD of Group 2 was 46.5 mm (no far PD of Group 1 was available), while the average far PD of Groups 5 and 6 were 51.0 mm. A plateau occurred

with the Groups 5 and 6 each having the same mean PDs at both distances. A one way analysis of variance (ANOVA) with a 90% level of significance, with Scheffe F-test post analysis, revealed no significant difference between Groups 2 and 3 nor between Groups 4, 5, and 6 at near or far. A scattergram representing each child's PD (mm) versus their age is shown for both far and near. [See Figures 3 and 4] A paired t-test with 95% level of significance revealed no significant differences between males and females at either the near or far fixation distances. [See Table 2]

To ascertain whether a difference existed between investigators' measurements, a one way ANOVA for repeated measures with a Scheffe F-test post analysis, was used. No clinically significant difference was found between investigators.

DISCUSSION

It is clear that the photographic method is a successful technique for determining PDs in children under the age of six. It provides the examiner with a permanent record of the patient's PD without requiring an extended fixation period. This in turn improves the repeatability and accuracy of the PD measurement. The photographic method is difficult to use clinically due to the time needed for film processing. The use of a Polaroid or video camera would provide a medium for immediate PD measurements and make the photographic technique more clinically useful.

The photographic method was easy to use with most children. There was, however, some difficulty with the youngest age group in maintaining fixation at the 3 m distance. This difficulty was occasionally encountered with the older children as well, but not frequently.

A distant PD for Group 1 may be theoretically determined. Since, the difference between far and near PDs for Groups 2 through 6 ranged from 3.5 mm to 4.5 mm, the far PD for Group 1 may be comfortably extrapolated to be 3.5 mm to 4.5 mm larger than the near PD of 40.5 mm. This would result in a Group 1 far PD of approximately 44.0 mm to 45.0 mm.

When male and female PDs were compared, the male averages were larger for all age groups except Group 2 at near, in which the female average was larger. However, t-test results showed no statistically significant difference ($p < 0.05$) between males and females in any age group. [See Table 2] Previous research by Pryor reported that males and females have equal PDs at birth (4.0 cm) but by 3 months of age the male's PDs are larger and remains larger at least until the age of 5 years (2). Pryor found that males have a PD of 4.4 cm at 3 months of age and it increases to 5.1 cm by 5 years. While females have a PD of 4.3 cm at 3 months, which increases to 4.9 cm by 5 years of age. Caution should be used when comparing the values Pryor reported to those found in this study. Pryor calculated the interpupillary distance as a mathematical function of the two measured

intercanthal distances, while the photographic method used in our study was a direct measurement of PD. There is some question as to what fixation distance is represented by Pryor's results and the validity of the objective PD formula method which she used (2).

Future studies should establish norms for PDs on other races and also establish norms for the most common pediatric anomalies (i.e., Down's syndrome, Hydrocephaly, Microcephalus and other disorders) which can result in smaller or larger than normal PDs. Knowledge of the normal range of PD by age, and what is in fact abnormal, may be diagnostic for some of the syndromes mentioned. The measurement of bridge size, by age for different races, may also be useful information for the ophthalmic frame industry. This study established that the photographic technique was useful for measuring PDs in the early pediatric population and has helped to establish norms for this age group.

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- 6.) Hugo G. Bogren, Charles E. Franti, Stephen S. Wilmarth. Normal Variation of the position of the eye in the orbit. Ophthalmology Aug 1986. Vol. 93, No. 8, pp 1072-1077.

APPENDIX

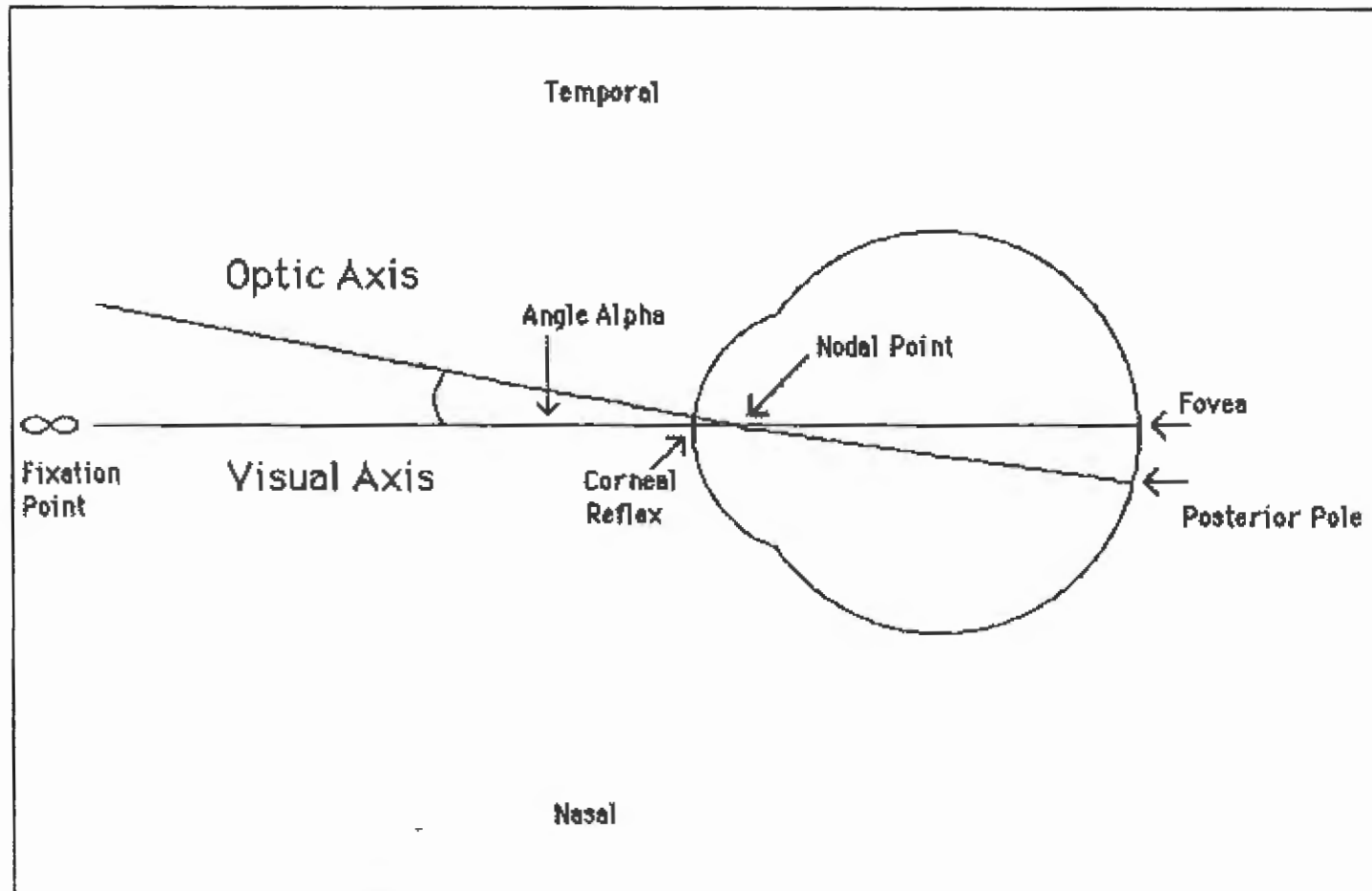


Illustration 1: Top view of right eye showing the position of the visual axis and optic axis.

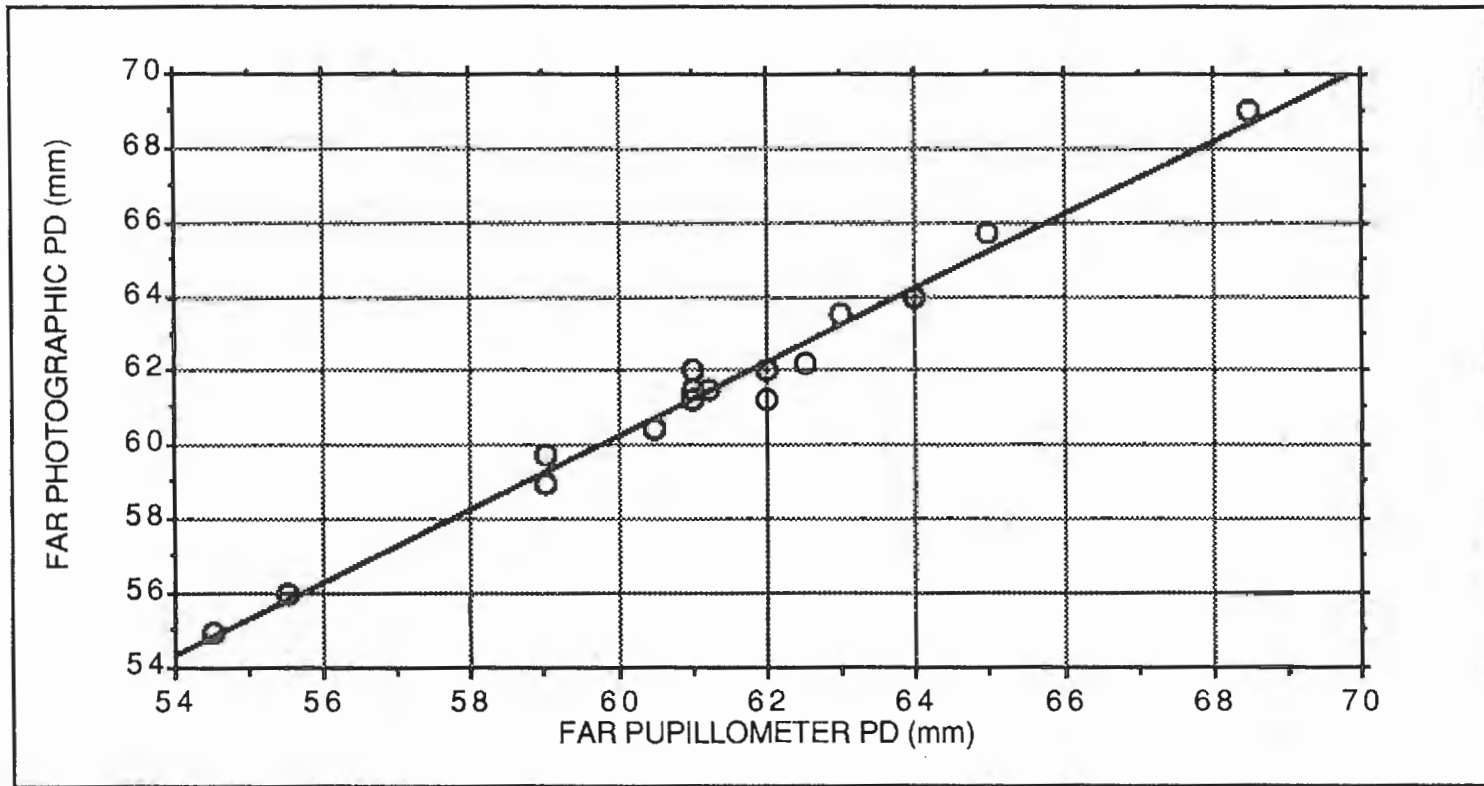


Figure 1: Correlation of Pilot Study results comparing photographic PD (mm) measurements to pupillometer PD (mm) measurements at far. Pearson $r=0.991$.

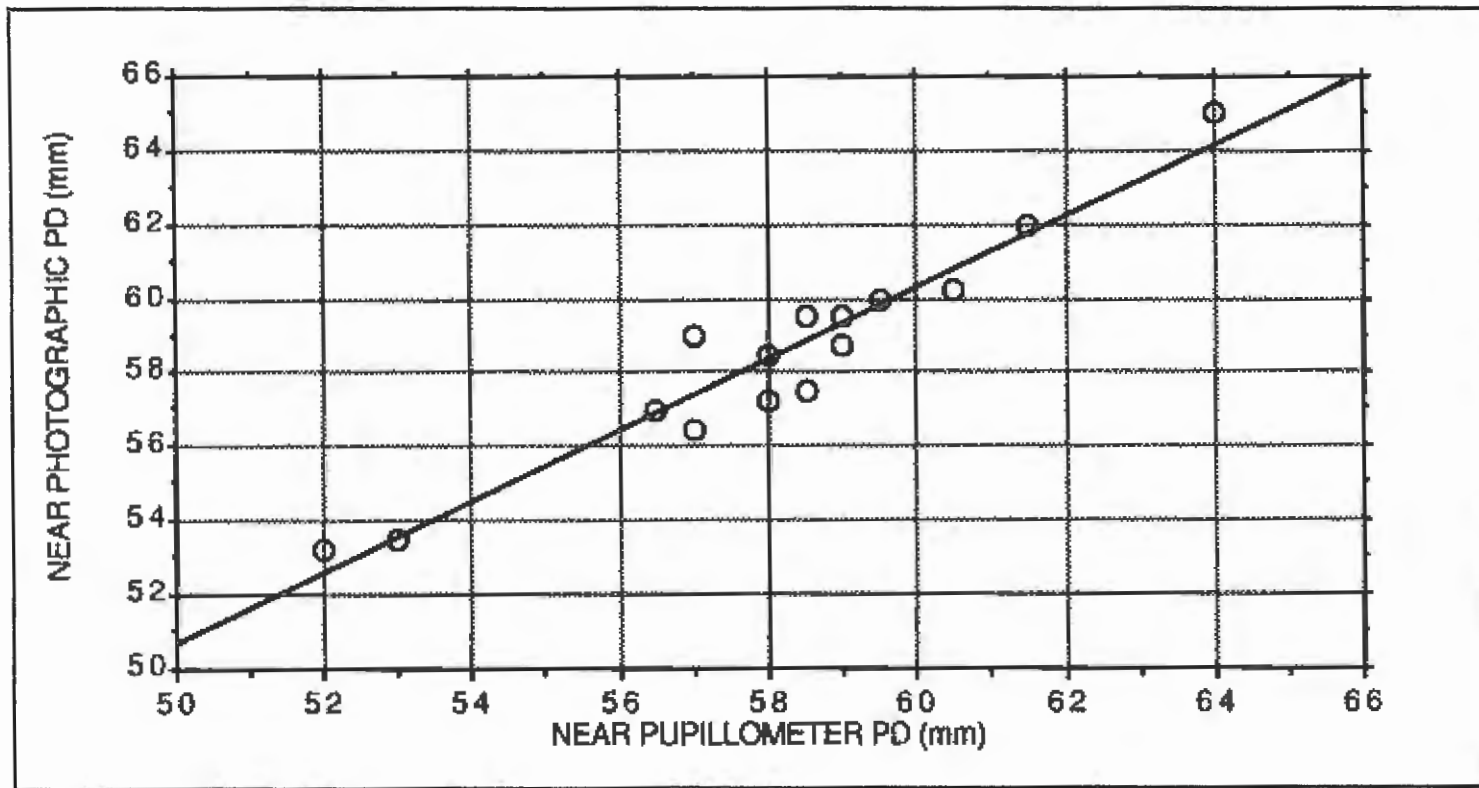


Figure 2: Correlation of Pilot Study results comparing photographic PD (mm) measurements to pupilometer PD (mm) measurements at near. Pearson $r=0.964$.

Table 1: Summary of results by age group.

GROUP NUMBER AGE (months)	MEAN AGE* (months)	n	GENDER (F=female M=male)	FAR INTERPUPILLARY DISTANCE (mm)		NEAR INTERPUPILLARY DISTANCE (mm)	
				MEAN† (SD)	RANGE	MEAN† (SD)	RANGE
GROUP 1 (0-11 mo)	5.5	38	F=16 M=22	N/A	N/A	40.5 (2.44)	35.00-45.00
GROUP 2 (12-23 mo)	18.0	41	F=18 M=23	46.5 (2.19)	42.88-52.25	43.0 (2.13)	38.75-47.38
GROUP 3 (24-35 mo)	28.5	36	F=21 M=15	47.5 (2.44)	41.13-52.88	43.5 (2.43)	38.88-48.00
GROUP 4 (36-47 mo)	41.5	31	F=15 M=16	49.5 (2.19)	46.38-53.63	46.0 (2.21)	43.00-50.75
GROUP 5 (48-59 mo)	53.5	42	F=24 M=18	51.0 (2.45)	46.25-55.25	46.5 (2.86)	40.75-52.63
GROUP 6 (60-71 mo)	64.5	32	F=18 M=14	51.0 (2.77)	45.38-56.25	46.5 (2.69)	41.17-52.75

* Rounded to nearest 0.5 mo

†Rounded to nearest 0.5 mm

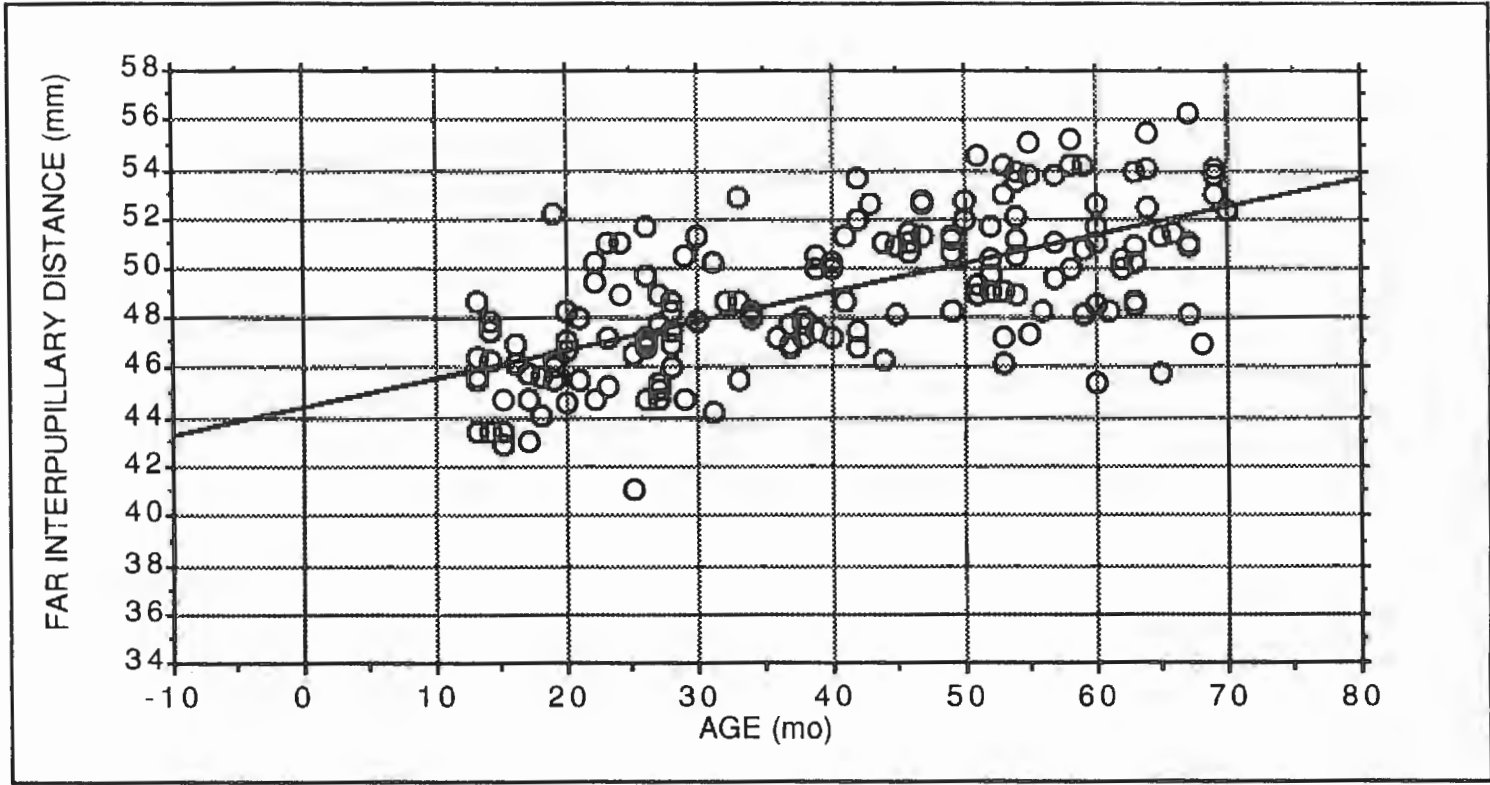


Figure 3: Scattergram with points representing each subject's far PD (mm) vs. their age (mo).

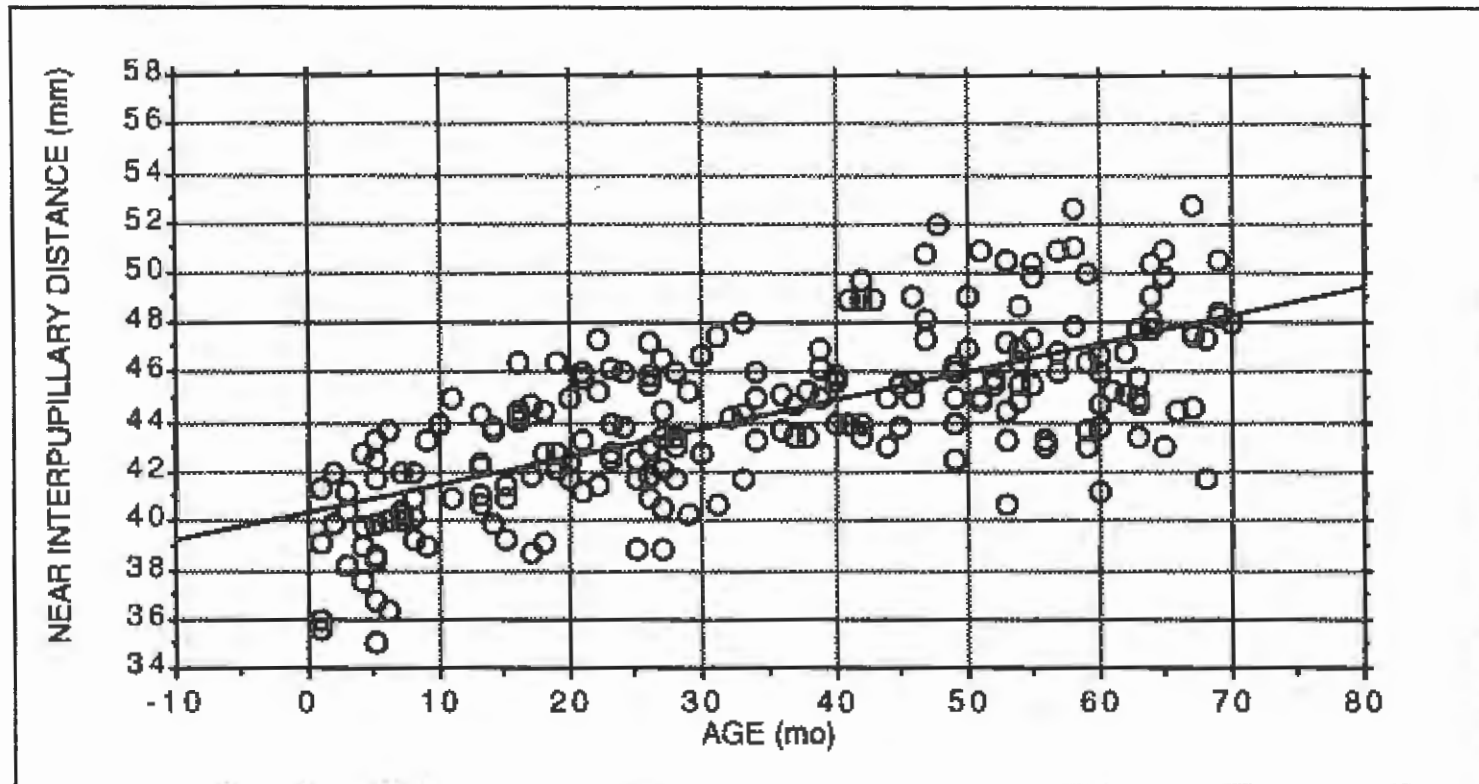


Figure 4: Scattergram with points representing each subject's near PD (mm) vs. their age (mo).

Table 2: Summary of results by gender and t-test results comparing females to males in each age group.

GROUP NUMBER Age (months)	GENDER	MEAN AGE* (months)	n	FAR INTERPUPILLARY DISTANCE (mm)		FAR MEANS (t-TEST)	NEAR INTERPUPILLARY DISTANCE (mm)		NEAR MEANS (t-TEST)
				MEAN† (SD)	RANGE		MEAN† (SD)	RANGE	
GROUP 1 (0-11 mo)	FEMALES	5.0	16	N/A	N/A	N/A	40.0 (2.36)	35.00-43.25	p=0.5087
	MALES	6.0	22	N/A	N/A	N/A	40.5 (2.52)	35.63-45.00	ns (p>0.05)
GROUP 2 (12-23 mo)	FEMALES	18.0	18	45.5 (1.94)	42.88-50.22	p=0.1796	43.5 (2.27)	39.25-47.38	p=0.6511
	MALES	17.5	23	46.5 (2.29)	43.00-52.25	ns (p>0.05)	43.0 (2.06)	38.75-46.50	ns (p>0.05)
GROUP 3 (24-35 mo)	FEMALES	28.0	21	47.5 (2.64)	41.13-51.75	p=0.6405	43.5 (2.60)	38.88-47.50	p=0.5618
	MALES	28.5	15	48.0 (2.17)	44.75-52.88	ns (p>0.05)	44.0 (2.23)	41.00-48.00	ns (p>0.05)
GROUP 4 (36-47 mo)	FEMALES	41.0	15	48.5 (2.12)	46.38-52.75	p=0.0663	45.0 (1.68)	43.00-49.00	p=0.0938
	MALES	42.0	16	50.0 (2.06)	46.88-53.63	ns (p>0.05)	46.5 (2.49)	43.50-50.75	ns (p>0.05)
GROUP 5 (48-59 mo)	FEMALES	54.0	24	51.0 (2.31)	47.25-55.25	p=0.4538	46.5 (2.70)	42.50-52.00	p=0.917
	MALES	53.5	18	51.5 (2.65)	46.25-54.63	ns (p>0.05)	47.0 (3.13)	40.75-52.63	ns (p>0.05)
GROUP 6 (60-71 mo)	FEMALES	64.0	18	50.5 (2.43)	45.75-51.13	p=0.3649	46.0 (2.61)	41.75-50.88	p=0.1887
	MALES	64.5	14	51.5 (3.19)	45.38-56.25	ns (p>0.05)	47.5 (2.72)	41.17-52.75	ns (p>0.05)

* Rounded to nearest 0.5 mo

†Rounded to nearest 0.5 mm

ns=not significant