An evaluation of pupil size standards used by police officers for detecting drug impairment

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Background: The Drug Evaluation and Classification (DEC) program was developed to detect, arrest, and convict drivers impaired by drugs other than alcohol. The DEC program is a training program designed to prepare police officers and other qualified persons to serve as Drug Recognition Experts (DREs).

Purpose: The purposes of this study were: (1) to determine normative values and ranges for pupillary responses using the specific DEC program protocols for pupil testing in non-impaired persons, and (2) to appraise the suitability of the 3.0- mm to 6.5-mm pupil range as a potential sign of impairment under three conditions.

Methods: Trained DRE officers measured pupil sizes using standardized DEC protocols. Pupil measurements were taken under three light levels: room light, near-total darkness, and direct light. The subjects were 250 volunteers, with an average age of 29.2 years (±6.1). All subjects were healthy, non-impaired, and free of visual, and/or neurological problems.

Results: For each pupil measured ($N = 500$), the mean (SD) for each of the three test conditions were: room light 3.86 (0.93) mm; near-total darkness 6.41(1.55) mm; and direct light 3.35 (0.72) mm.

Conclusions: This study determined normative values and potential ranges for pupillary responses using the specific DEC program protocols for pupil testing in non-impaired persons. When the presently approved DEC program pupil size range (3.0 to 6.5 mm) is compared with the results of this study, it appears that the DEC range for pupil size might be too sensitive. However, when determining impairment related to drug(s), the DRE reviews the results of all tests and draws a conclusion based on the totality of the evidence, not only on a variation in the pupil size.

Key Words: Drug Evaluation and Classification program, drug recognition expert, drugs, law enforcement, pupils, substance abuse

Substance abuse continues to be a significant problem in our society, with millions of adolescents and adults using illicit drugs. One strategy for management of this problem is the use of a standardized method by law enforcement for detection and evaluation of impaired individuals. This program is called the Drug Evaluation Classification (DEC) program, which trains officers to be Drug Recognition Experts (DREs) or Drug Recognition Evaluators, depending on the state in which the program is used. To become a DRE, a police officer must complete a 72-hour classroom instruction and field training program, pass a written examination program, and complete field examinations (successfully identifying an individual under the influence of drugs in specific drug categories on at least 12 subjects) under the supervision of a trained DRE instructor. Finally, the officer must pass a final written examination and a separate skills demonstration examination before becoming certified as a DRE.

When is a DRE evaluation performed and what is involved in a complete evaluation? An individual may be stopped by a traffic officer based on probable cause for a driving infraction or involvement in a crash. If alcohol or drug use is suspected—based on standardized roadside tests—the officer will place the suspect under arrest. Then a DRE evaluation may be requested by the arresting officer if the suspect's inconsistent behavior is suggestive of possible substance use. (This evaluation, when requested, is administered by a DRE as quickly as is physically possible.) The DRE will use a 12-step process for identification of potential substance use and impairment.[1] *First*, an alcohol breath test is used to confirm the presence or absence of alcohol. *Second*, the DRE interviews the arresting officer regard-

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ing the events and condition of the suspect arrested for such things as possession of any drugs or drug paraphernalia. *Third*, based on all the previous information, a preliminary examination is performed to determine whether the observed behavior is due to drug use or a medical problem that requires medical attention. The overall condition of the suspect is observed and an initial pulse rate is taken. In the *fourth* step, the drug recognition evaluation continues with an examination of the eyes by assessing horizontal gaze nystagmus, vertical gaze nystagmus, and lack of convergence. Step *five* is the divided attention test, including the Walk and Turn, One Leg Stand, Finger to Nose, and Rhomberg test. Then, in step *six*, the DRE takes a second look at the pulse rate, body temperature, and blood pressure. (Some vital signs may be high or low, depending on the drugs present, while some may not be affected at all.) The dark room examination is step *seven*, in which the DRE evaluates the pupils of the suspect's eyes under three different lighting conditions: room light, low light, and direct light. Because certain drug categories affect the pupils, causing either dilation or constriction, this examination can provide additional evidence of the possible influence of drugs on the suspect.

In steps *eight* and *nine*, the DRE checks the muscle tone in the suspect's arms for evidence of drug use. Certain drug categories will cause the muscles to become rigid, while others may cause the muscles to become flaccid. A third pulse is taken at this time.

From these first nine steps, the DRE will have determined if the suspect could be under the influence of a substance and, if so, the likely category of substance that is affecting the suspect. In the *tenth* step, the DRE interviews the suspect about substance use, with strict compliance as to the suspect's Constitutional rights.

In the *eleventh* step, the DRE will form an opinion about the suspect's physical and mental condition and the possible category(s) of substances involved. This opinion is then written in a report, with specifics as to the reason for this opinion. Finally, in the *twelfth* step, the DRE obtains a blood or urine specimen, which will be sent to a laboratory for chemical analysis for admissible scientific evidence, substantiating the DRE's determination.

The focus of this study is specifically on the seventh step, involving the assessment of pupil responses and size under three different standardized lighting conditions. For non-impaired normal subjects, the present Drug Recognition Expert program criterion considers the normal non-impaired pupil size to be in the range of no less than 3.0 mm to not more than 6.5 mm under any of three different conditions.[2] These conditions, in which the pupil size is measured, are: (1) room light, (2) near-total darkness, and (3) direct light. Pupil sizes above or below these values in these conditions may be considered suspicious for the presence of drugs.

However, there are various studies that have used normal subjects which suggest that the DEC program range of pupil sizes of 3.0 to 6.5 mm may be too narrow. Loewenfeld and Lowenstein[3] found many subjects had pupil sizes in near-total darkness significantly greater than 6.5 mm. Birren et al.[4] also reported mean pupil sizes greater than 6.5 mm in dark room conditions following 90 seconds of dark adaptation. Using infrared pupillometry, Borgmann[5] measured the pupil diameter in darkness and found mean values for the pupil size to be greater than 6.5 mm. Loewenfeld,[6] in a study of more than 1,200 subjects, replicated earlier work, and further reported a mean pupil size value larger than 6.5-mm in darkness.

With the introduction of refractive surgery, the pupil size under (scotopic) conditions of near-total darkness was of clinical interest.[7] Recent studies using infra-red and video techniques to measure the pupil in darkness again reported pupil sizes that had broader ranges for normal subjects than the Drug Evaluation and Classification Program. Colvard[8] measured the pupil sizes of 100 patients with a mean age of 28 years. Using the pupillometer, the mean pupil size in scotopic conditions was 6.2 mm (with a range of 3.0 to 9.0 mm).[8] Schnitzler et al.,[9] using an infra-red pupillometer under scotopic light conditions, reported similar results as the previous authors, with a mean pupil diameter of 6.16 mm ± 1.20 (SD) (range, 3.20 to 9.00 mm).[9] Five additional studies have consistently supported and further confirmed that the normal scotopic pupil size range is approximately 4 to 9 mm for healthy non-impaired subjects.[10-14]

When the recommended DEC program normal pupil size range (3.0 to 6.5 mm) is compared with these earlier works, the present DEC range
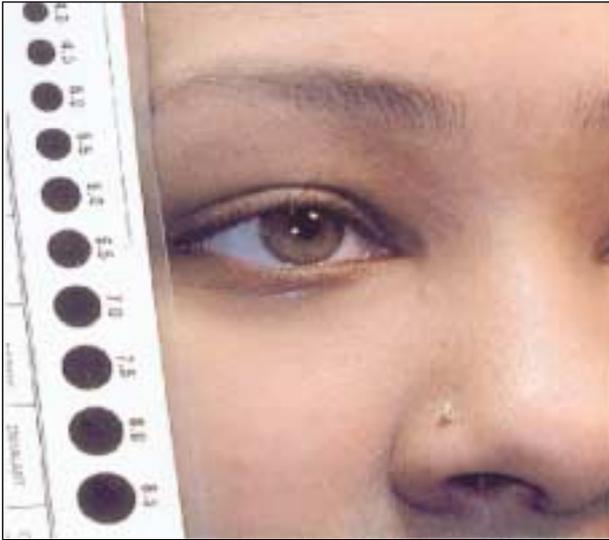
Figure 1 Measuring pupil size in room light.

appears potentially limiting. However, the DRE reviews the results of all tests in the DEC protocol before drawing a conclusion. *The decision as to whether or not impairment is present is based on the totality of the evidence, not simply a variation in the pupil size.* Since there are no published age-related normative pupil values in the literature using these three specific Drug Evaluation and Classification program protocols for pupil examination, the purpose of this study was to determine and compare normative sizes of pupils (based on pupillary responses)—using the three specific program protocols in pupil testing—to previous studies.

Method

Subjects

The subjects were adult volunteers from police training programs, as well as civilian volunteers ($N = 250$), in multiple sites in the New England area. The average participant age was 29.2 years of age (± 6.1). Ninety percent were white; 13% were women and 87% were men. Forty percent of the subjects had either blue, hazel, or green irides (blue group), and 60% had brown irides (brown group). They were all reportedly in excellent health, with no physical, visual, and/or neurological problems that could have affected pupillary function. They were reportedly drug and alcohol free at the time of testing, and were screened for possible drug use by administering the Drug Evaluation and Classification program protocol without toxicological samples at the time

of testing. However, many of the subjects (82%) had been screened for drugs with urine testing and were negative within the past 30 days, and were subject to random testing as a requirement of the police training program.

Protocol

All four examiners were certified Drug Recognition Expert police officers from various law enforcement agencies. There were multiple testing sites. Each examiner tested a different subject. The distribution of the number of subjects tested by each examiner was relatively equal (range, 55 to 70 subjects per examiner). The examiners used standardized procedures, using a penlight and pupillometer, following protocols specifically described in the National Highway Traffic Safety Administration DRE training manual (2002)[15] for estimating pupil size. Pupil sizes were measured using a standard white card pupillometer with black circles in 0.5-mm increments under three different lighting conditions: room light, near-total darkness (scotopic), and direct light (photopic). The brightness of the penlight stimulus was standardized for all examiners. For direct light measurement of pupil size, the illuminance was a minimum of 20 foot-candles on the ocular and pupil area.

The specific directions that are recommended in the Drug Evaluation and Classification training manual for measuring each of the three conditions are as follows:[15]

Room Light (Figure 1)

"Hold the pupillometer alongside the subject's eye. Instruct the subject to focus on a specific point behind the examiner and slightly above the subject's eye level. Use the same point for the dark room examinations. Make sure the pupillometer is even with the eyeball (neither closer to you nor farther from you than is the subject's eyeball). Move the pupillometer up or down until you find the darkened circle that appears to be approximately the same size as the subject's pupil. Check the left eye and then the right eye."

Record the pupil size to the nearest 0.5 mm for each eye on the recording face sheet.

Darkroom/Near-Total Darkness (Figure 2)

"After you have completed the pupil size estimations in room light, you must darken the room, wait 90 seconds, then proceed with the

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darkroom examination. For the check under near-total darkness, hold your finger over the tip of the penlight, so that only a reddish glow emerges."

Record the pupil size to the nearest 0.5 mm for each eye on the recording face sheet.

Direct Light (Figure 3)

"For the check under direct light, bring the light from the side of the subject's face, directly into the eye. Assessment of the pupil's reaction to light takes place immediately before the check of pupil size under direct light. Once again, start by bringing the uncovered light from the side of the subject's face directly into his or her left eye. As you bring the beam of light directly into the subject's eye, note how the pupil reacts. The penlight should be positioned so that the beam just 'fits' the eye socket. Under ordinary conditions, the pupil should react very quickly, and constrict noticeably when the light beam strikes the eye. Under the influence of certain categories of drugs, the pupil's reaction may be very sluggish, or there may be no visible constriction at all.

Hold the direct light on the subject's eye for 15 seconds to assess pupil reaction. Also check for hippus or rebound dilation during this 15-second period. When you have completed this process for the left eye, repeat it for the right eye and record."

Record the pupil size to the nearest 0.5 mm at the end of 15 seconds for each eye on the recording face sheet.

The results were recorded for each of the three conditions in a manner consistent with the Drug Evaluation and Classification standardized protocol.

Validity of examiners pupil measures

To establish the validity of the subjective pupil size estimation by the examiners, an objective measure of pupil size was used. Videography was performed under photopic and scotopic pupil size measurement conditions; a Sony DCR-TRV103 digital video camera recorder, equipped with an infra-red emission source and still picture capability, was used. A pupillometer scale was incor-
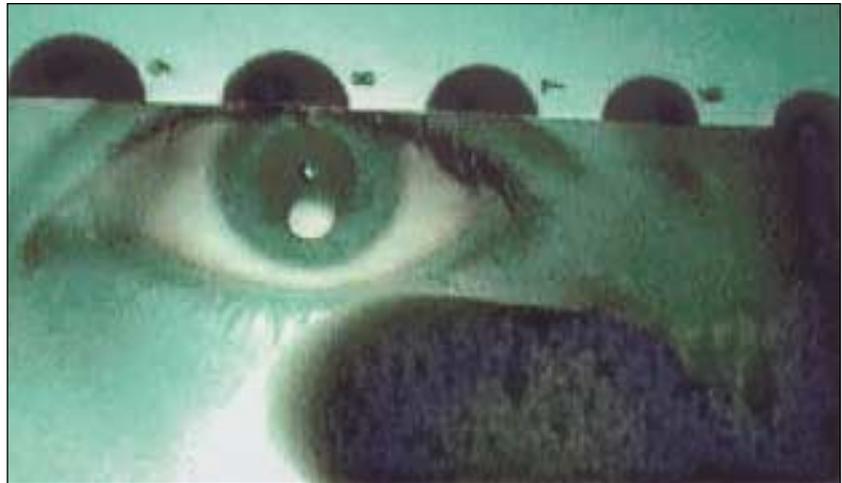

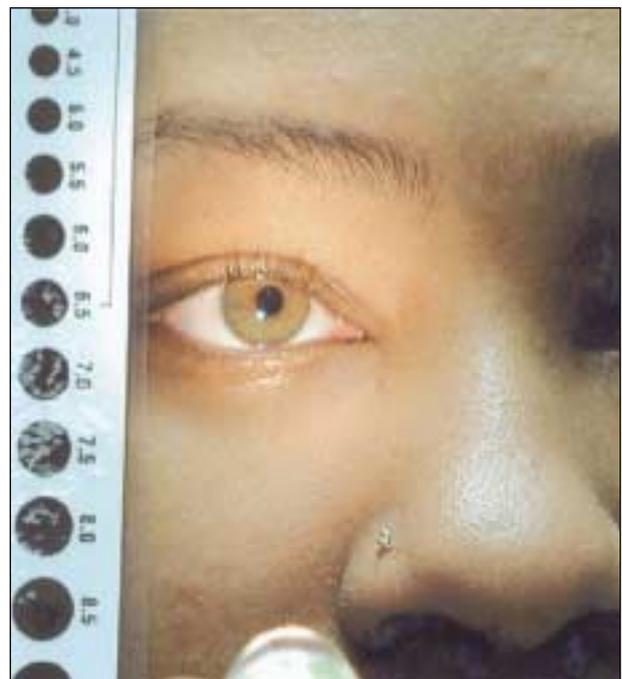**Figure 2** Measurement of pupil size in the darkroom (near-total darkness).

Figure 3 Measurement of pupil size with direct light.

porated into each digital picture. This allowed measurement of the pupil size against a standard within each picture, as can be seen in Figures 1, 2, and 3. Videography was used to determine the pupil size in a random sample of 20% of the subjects ($n = 50$) in two of the three conditions (i.e., near-total darkness and direct light). The potential affect of iris color on pupil size was investigated. In this random sample, one group was comprised of blue, green, and hazel irides (blue group, $n = 28$); the other consisted of brown irides (brown group, $n = 32$). These objectively recorded pupil sizes were taken at the same time
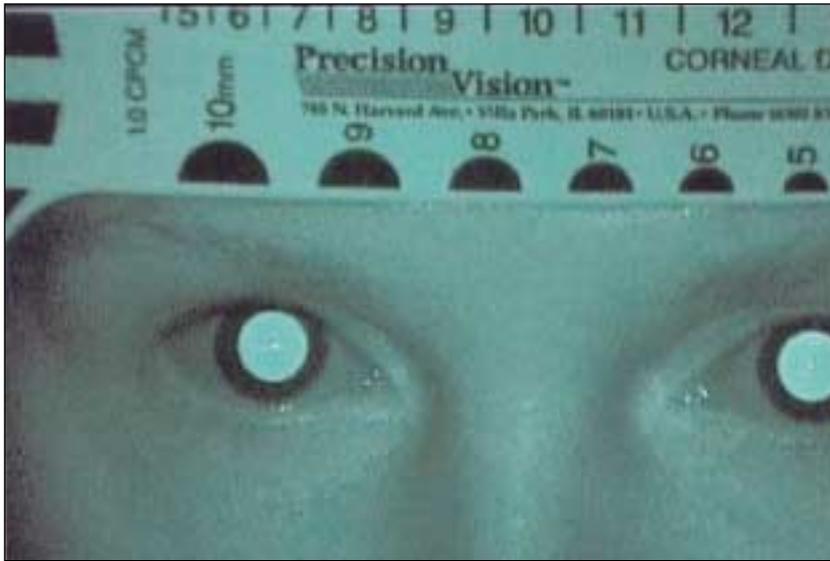
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Figure 4 Measurement with a pupillometer scale using an infra-red digital photograph in near-total darkness.

Table. The mean, median, and standard deviation are reported for each of the three test conditions for each pupil measured (N = 500)

Conditions	Pupil size Mean (SD) in mm	Pupil size Median in mm
Room light	3.86 (0.93)	3.62
Near-total darkness	6.41 (1.55)	6.45
Direct light	3.35 (0.72)	3.40

the subjective measure of pupil size in near-total darkness and direct light conditions was assessed by the evaluator. There was a relatively equal distribution of random videographic samples taken for each of the four evaluators. The videographic pupil size results were rounded to 0.5-mm increments, consistent with the subjective measures. An example of the objective measurement with a pupillometer scale, using an infra-red digital photograph in near-total darkness, is shown in Figure 4.

Results

The mean, median, and standard deviation values are reported for each of the three test conditions for each pupil measured. Since this is a normative study for the descriptive statistics of each of the three conditions, we used the pupil size for each eye measured in the 250 subjects ($N = 500$). The reported means and standard deviation (based on $N = 500$ eyes) assumes that looking at each pupil can be considered an inde-

pendent observation. The results are listed in Table 1. A chart of the frequency distribution of pupil sizes for each of the test conditions is shown in Figure 5.

To assess the relationship between the pupil size in the three conditions, only the results for each of the three conditions for the right eye of each subject were used. Though it may seem intuitive that the means for the three pupil test conditions are different, a one-way analysis of variance (ANOVA) with repeated measures was performed to assess the variation between samples, and between subjects, then compared against the error variance. The results revealed there was a significant difference in mean pupil size between the three test conditions ($F = 3.45$; $p < 0.0001$).

A subsequent analysis of the effect of the iris color was performed on the three test conditions. A two-way repeated measures ANOVA for color vs. pupil size was performed. The mean pupil size for room light, near-total darkness, and direct light in the blue eye group ($n = 100$) was 3.86 mm, 6.39 mm, and 3.34 mm, respectively. For the brown eye group ($n = 150$), the mean pupil size for room light, near-total darkness, and direct light was 3.89 mm, 6.55 mm, and 3.34 mm, respectively. There was no significant difference in pupil size between the three conditions as a function of the iris color ($F = 0.16$, NS). These conclusions are consistent with another report that investigated the effect of iris color (blue vs. brown) on the pupillary light reflex in normal healthy volunteers using objective measures only, which reported that the pupil size was independent of iris color.[16]

Validity of examiners pupil measures

For examiner validity and reliability of pupil size measurement, a paired t test for paired groups was performed using the results from the data for the right eye only of each subject. The purpose
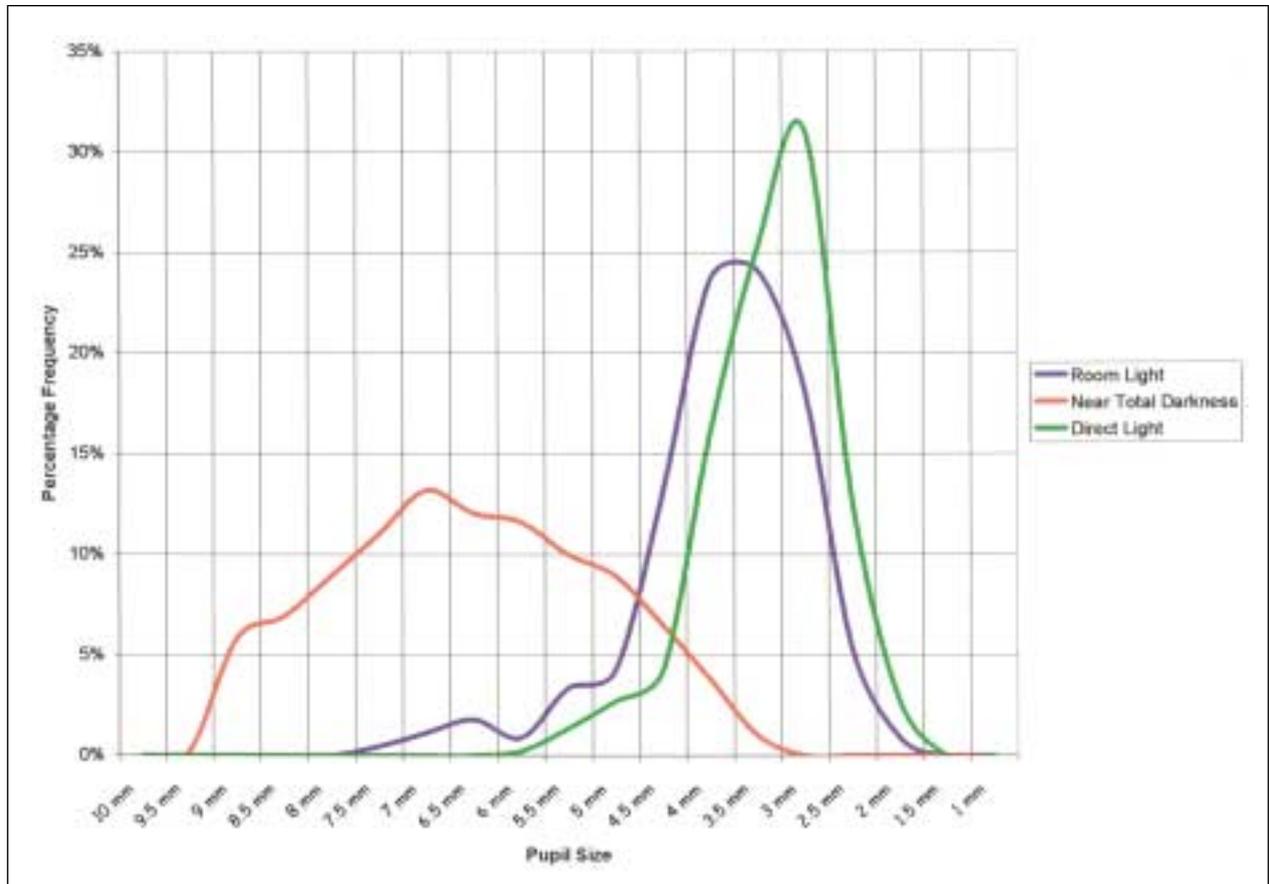
Figure 5 The frequency distribution of pupil sizes for three conditions.

was to determine if there was a significant difference between the subjective pupil measure and the objective videographic measure for direct light (photopic) and near-total darkness (scotopic) conditions.

For the blue eyed group, there was no significant difference in pupil size for the conditions of direct light ($t = -1.25$, NS) and near-total darkness ($t = -2.08$; NS). However, for the brown eyed group, there was a slight but statistically significant difference in pupil size measures for the near-total darkness condition ($t = -4.63$; $p < 0.01$). There was a mean difference of 0.26 mm between the subjective and objective measures under this test condition.

Discussion

This study determined, for the first time, normative values and ranges for pupillary responses in each of the three specific Drug Evaluation and Classification program protocols for pupil testing in a sample of 18- to 34-year-olds. The average age

of the subjects was 29.2 years of age (± 6.1), with almost 90% between the ages of 23 to 32 years. The frequency distribution of the subjects by age is shown in Figure 6.

This age range was selected because individuals in this range are considered at a greater risk for substance abuse.[17,18] Based on the results of this normative study, we determined the mean and standard deviation pupil size for the three test conditions. These findings are consistent with previous studies of pupil size—especially under the condition of near-total darkness as described previously. Our analysis showed there was a distinct difference in pupil size ranges when tested under the three different test conditions, as defined by the Drug Evaluation and Classification program protocols. In addition, iris color does not have a significant effect on the pupil size in the three test conditions.

For non-impaired normal subjects, the present Drug Evaluation and Classification program
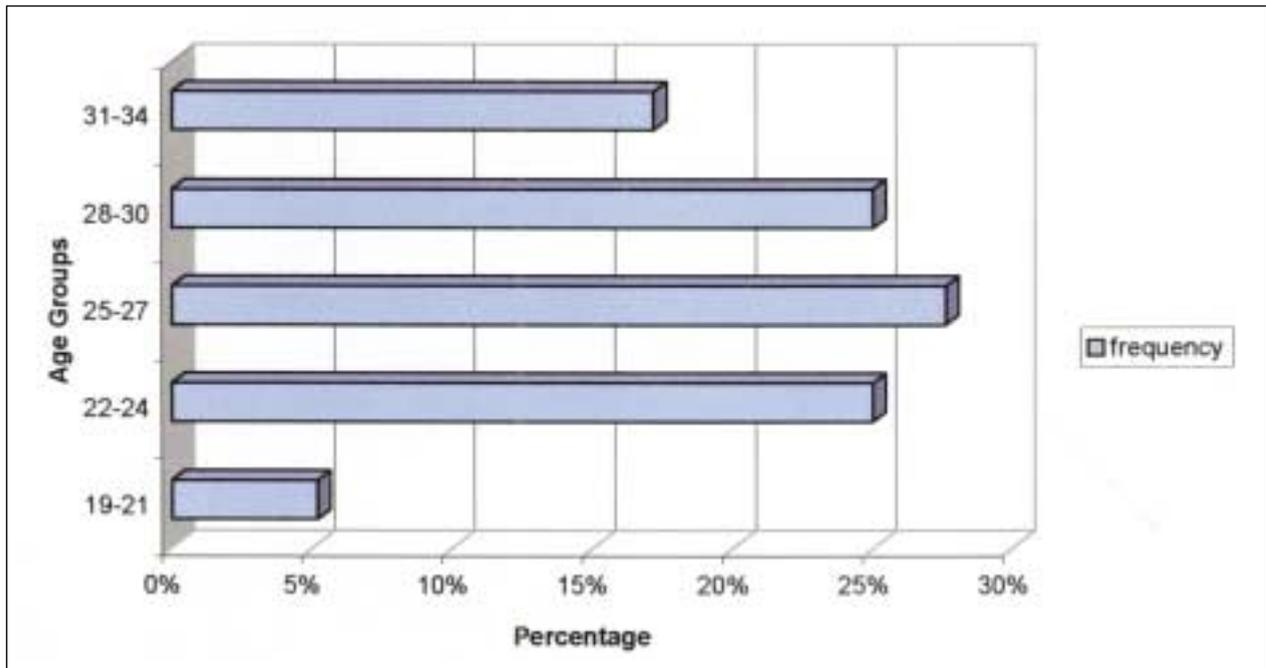
Figure 6 The frequency distribution of the subjects by age.

criterion considers that pupils in normal non-impaired subjects should neither constrict below a diameter of 3.0 mm nor dilate to a diameter greater than 6.5 mm in all three test conditions.

The objective of a Drug Evaluation and Classification evaluation is to determine if a person is under the influence of a drug or not and, if impaired, what is the most likely category(s) of drug(s) causing the impairment. This opinion is neither a guess nor a hunch. It is an informed opinion that is based on the totality of a standardized evaluation. Although opinions often have a subjective component, the Drug Recognition Expert "opinion" is based, in large part, on the use of specific test results and criteria.

Since our results indicated there were significant differences between the mean pupil size in the three test conditions, the use of three distinct pupil size ranges for each of the different testing conditions may be considered more useful in the evaluation.

In summary, the purposes of this study were: (1) to determine normative values and ranges for pupillary responses using the specific DEC program protocols for pupil testing in non-impaired persons, and (2) to appraise the suitability of the 3.0-mm to 6.5-mm pupil range as a potential sign of drug use and impairment. When the recommended DEC program normal pupil size range (3.0 to 6.5 mm) is compared with the results of this study, the present DEC range may be too narrow. It should be stressed that once pupil sizes are measured as part of the evaluation process, the DRE then reviews the results of all tests and draws a conclusion based on the totality of the evidence, not merely a variation in the pupil size. The use of the results from this study is intended to assist with the quality and accuracy of the DRE evaluation.

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