**Article**

# Predicting Biological Profiles from Prescription Eyewear: A Pilot Study

***Gregory E. Berg***
***Sabrina C. Ta'ala***

***Joint POW/MIA Accounting Command***
***Central Identification Laboratory***
***Hickam Air Force Base, HI***

**Abstract**: When unidentified human remains are recovered, valuable evidence to determine identity often comes from the nonskeletal material associated with those remains. In light of this observation, the following study presents a test of the hypothesis that, in cases where prescription glasses are found in association with human remains or at a crime scene, data from those glasses may be used to estimate the wearer's age, sex, or race. The study utilized data from the prescription glasses or current eye exams of 97 volunteers. Each anonymous volunteer provided information about his or her age, sex, and race. An automated lens analyzer was used to read prescriptions from glasses provided by volunteers, and the glasses were then returned to volunteers using a drop-off box with an anonymous numbering system. Data collected from lenses and prescriptions were compared to two large databases comprised of eyeglass prescriptions from more than 12,000 individuals in a variety of age, sex, and racial categories. To attempt to estimate the age, sex, and race of the study volunteers from their prescriptions, three methods were applied. The results of the study indicate that one of the methods for estimating age within ±10 years had an 81% accuracy rate; age (±10 years) was correctly predicted in 100% of cases with bifocal prescriptions (n=31). Sex and race could not be estimated with sufficient accuracy using any of the three methods applied in this study. Although the study resulted in the null hypothesis in terms of estimating sex and race using prescription lenses, the ability to estimate an unknown individual's age would be useful in many cases, particularly in instances of advanced age, where traditional age estimation methods fare poorly. Such a method could also prove invaluable in the (albeit rare) instances where a perpetrator leaves glasses behind at a crime scene.

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## Introduction

Forensic investigators are sometimes faced with cases of unidentified human remains, where a biological profile must be established to make an identification. A basic biological profile is often difficult to establish in cases of advanced skeletonization, particularly in instances where significant skeletal elements are missing. In such cases, associated evidence (e.g., clothing and personal effects) is crucial to consider. In addition, occasionally, clothing or personal items are left at a crime scene by a perpetrator, and these can be used to assist in identifying potential suspects. This pilot study explores a possible avenue to assist in personal identification in cases where prescription eyewear is found at a crime scene or is associated with unidentified remains. We hypothesize that eyeglass prescriptions (to compensate for refractive errors) have predictive power for certain biological parameters such as age, sex, and race. A brief description of refractive error is presented, followed by details of the methods used and the results obtained in this study.

## Materials and Methods

### *Refractive Error and Personal Identification*

Many people rely on prescription lenses to compensate for refractive errors in their vision. Refractive errors occur when light waves fail to focus on the retina, resulting in blurred vision. Left and right eyes usually have similar or complementary refractive errors, but extremely different refractive errors may occur between the two eyes. Although refractive errors are very common in the general population (~55% of individuals require correction for refractive errors), individual prescriptions, when compared against the total refractive error universe, are typically rare, very rare, or unique. The number of potential refractive error states a single eye can occupy is 1,152,000, and when a pair of eyes is considered, the possible combinations exceed one trillion [1]. In general, the more severe the refractive error, the more unique it is within a population. Therefore, in more than half of the current population, eyewear can be an extremely useful evidentiary tool for personal identification [1]. In fact, eyewear has been used as corroborating evidence in at least three personal identification cases at the Joint POW/MIA Accounting Command-Central Identification Laboratory

(JPAC-CIL), has been used in several other cases reported in the literature [2-5], and recently was used in a homicide conviction *(sans corpus)* in Honolulu, Hawaii.

Myopia, hyperopia, and astigmatism are the three primary types of refractive error, also referred to as ametropia. Myopia occurs when the optical system of the eye is excessively strong or when the eye is unusually long, resulting in the image falling in front of the retina. This leaves the image at the retinal surface out of focus. Hyperopia occurs when the optical system is too weak or when the axial length of the eye is short. In this case, the focal point falls past the retina, leaving the image blurry on the retinal surface. Astigmatism occurs when the cornea at the front of the eye is curved more in one meridian than another or from internal components of the eye. This results in the creation of two points of focus. Astigmatism can be found in combination with hyperopia or myopia. In conjunction with these common conditions, a correction is sometimes necessary for close vision. This is an additional focal length, typically known as an additional power or bifocal correction [1].

Refractive errors are measured by several variables: sphere power (sphere), cylinder power (cylinder), and the axis of the cylinder power (axis). Quarter diopter increments or optical powers typically are used for the sphere and cylinder powers measurements, though some practitioners use 1/8 diopter (0.125) measurements. The sphere correction does not usually exceed -15 diopters in a myopic category or +15 diopters in a hyperopic category, for either eye. Corrections for astigmatism (cylinder corrections) usually range from -0.25 diopters to -8.0 diopters, although on rare occasions can exceed -10 diopters (this is a minus cylinder format, the typical format used currently in the United States). The ranges exemplified here are the typical ranges for these variables, but some corrections will logically be outside of these ranges. The correction for the axis variable is a single degree increment, from 0 to 180 degrees. This number identifies the meridian requiring greater correction to create a single point of focus. Bifocal add powers typically start at 0.75 diopters and occasionally exceed 2.5 diopters in cases where individuals require a very short working distance. In those cases, bifocal powers may be as high as 4.0 diopters.

### *Study Sample*

Ninety-seven anonymous volunteers were solicited from among a mixed civilian and military population associated with the JPAC-CIL and the 15th Airlift Wing Optometry Clinic in Hawaii. Nearly all study participants (n=96) submitted their glasses with an information card that included their sex, age, and self-assigned race. Both prescription sunglasses and regular glasses were included among the donated glasses. One researcher (SCT) and a professional optometrist used a triple laser lens analyzer, the Humphrey 350 Lens Analyzer, to measure the prescription of each pair of glasses. (A lensometer measures the focal length and its orientation on a lens). The remaining individual had the prescription determined by a professional optometrist at the optometry clinic. The researcher who did not measure or record prescriptions (GEB) was then provided with the prescription data, devoid of the associated biological information. The second researcher conducted the comparative analyses to estimate the age, sex, and race for each volunteer. Individuals of mixed ancestry, or ancestry that is not well represented in the databases, were excluded from the study (n=7). The remaining (n=90) test group included 43 females and 47 males. Ages ranged from 19 to 76 years, with one individual under 20, 16 in their 20s, 28 in their 30s, 29 in their 40s, 11 in their 50s, 4 in their 60s, and one person over 70. The self-reported race of the dataset was as follows: White (26), Black (25), Asian (21), and Hispanic (18).

### *Databases*

Two main databases were used in this study: the National Health and Nutrition Examination Survey (NHANES) database and the Central Identification Laboratory Eyeglass Prescription Information (CILEPI) database. The NHANES database is derived from a multiyear study conducted by the National Center for Health Statistics on a United States population sample and recorded biological information on approximately 20,000 study participants [6]. Refractive error evaluations for 8,000 individuals from the NHANES database were utilized in this study; the remainder of the ~20,000 study participants had little to no detectable refraction error (they would not have sought optical treatment) or were excluded because of a lack of associated age data. The refined NHANES database includes slightly more females than males, ranging from 12 to 84 years in age, all with self-reported race. For the purposes of this study, the following self-reported races were used: White (42.7%), Black (22.4%), and Hispanic (34.9%).

The CILEPI database is composed of prescription data from a survey conducted at the Lackland Air Force Base Optometry clinic, Texas, and the 15th Airlift Wing Optometry clinic, Hawaii. Most survey participants were active duty military individuals, though their dependants and other militarily eligible individuals were included. The database contains over 4500 individuals with all having self-reported data on sex, age, and race. Most of the study participants were male, ranging in age from 4 to 95 years old. In this particular study, the database contains the following racial distribution: White (62%), Black (17%), Hispanic (13%), Asian (5%), Native American (2%), and Pacific Islander (1%).

The total study database size for most comparisons is 12,227. When the two databases are combined, the sex prevalence is male, though the racial breakdown is modified to White (50.0%), Black (20.4%), Hispanic (31.7%), Asian (1.7%), American Indian (0.6%), and Pacific Islander (0.5%). Because the categories of American Indian and Pacific Islander are extremely small in the databases, those individuals were eliminated from consideration in the estimation methods, leaving only four races for the purposes of this study: White, Black, Hispanic, and Asian.

*Estimation Methods*

Three different methods were developed and assessed in terms of their predictive capabilities for the age, sex, and race of an unknown individual. The methods were devised using either an exact match frequency or a tolerance match frequency. The term *match* in this study means that the input prescription is identical to another prescription in the databases, given the query parameters. The term *frequency* refers to the number of matches to a given prescription in the databases. The methods can be categorized generally from the most specific (least conservative estimator) to the least specific (most conservative estimator).

A more conservative estimate of the frequency of any one prescription is called a tolerance match; these matches take into account slight variations in patient vision as well as small manufacturing errors. A ±0.25 diopter variation for the sphere and cylinder categories and a ±3 degree variation for the axis category are the values used for a tolerance match. Further, tolerance matches may be a better predictor of the biological profile of an individual for two specific reasons. First, exact matches are rare for eyeglass prescriptions because of the large number of refractive error combinations eyes can attain [1]. Second, the refractive error of eyes may be linked by age, race, or sex. Other investigators have found that certain populations and age groups have consistently differing amounts of myopia, hyperopia, and astigmatism [7-10]. Therefore, we hypothesized that the refractive error from like groups (racial populations, age groups, etc.) would cluster together, thereby giving predictive power to prescription data for various biological parameters.

The most specific method (method #1) was a tolerance match to each of the three variables for a given prescription (sphere, cylinder, and axis). Although this would appear to be a somewhat conservative method because it is a tolerance match, the inclusion of the axis variable introduces a much greater number of potential refractive error combinations (32,400 possible combinations per pair of eyes) than the other methods. The second method (method #2) was an exact match to only the sphere and cylinder powers of both eyes. This method typically produced between zero and ten matches per prescription. The most conservative method (method #3) was a tolerance match to the sphere and cylinder powers of both eyes. This model took into account the widest variety of prescriptions around and including the target prescription and did not have the compounding factor of the axis variable. Frequently, this method would return tens to hundreds of matching prescriptions.

For the analysis, a query was written to each database based on the criteria of the method. All matching responses were then used to predict the sex, age, and race of the target prescription. Because of the low number of matching prescriptions for any method, estimates were produced only if at least three matching prescriptions were returned. Sex predictions were calculated as the number of males and females from the query divided by the number of males and females in the databases. If no clear prediction was possible (e.g., male = 53%, female = 47%), then the variable was scored as unknown. Sex estimates were judged correct if they matched the recorded sex of the known individual.

An age interval was constructed for each case that met the minimum criteria. Age intervals were the mean age of all returned prescriptions and a ±10 year range. Since an age interval is a standard reporting method for forensic anthropology, and it is well accepted in law enforcement circles, we believe this method is a reliable way to judge the accuracy of the predicted age. In cases with bifocal corrections, age estimates were conducted solely from this variable, because bifocal prescriptions are highly linked to age. Only the CILEPI database was used for age estimates from bifocal prescriptions, because the NHANES database does not contain this information. The racial estimate was constructed by computing the frequency of the prescription in a given racial group, similar to that of the sex estimate. For example, if 34 matches were returned from a prescription for White individuals and 18 for Black individuals, the resulting frequencies would be 0.0056 (34/6118) for Whites and 0.0072 (18/2494) for Blacks. To determine whether the number of responses to each query affected the predictive ability of the method, two analyses were conducted, those with greater than ten responses and those with ten or fewer responses. Finally, the percentages of correct predictions for each category were calculated, per category.

The first 30 prescriptions were utilized in a preliminary test. Through this process, it became clear that methods #1 and #2 were deficient in predictive power. With both methods, more than half of the query prescriptions (18 and 16, respectively) showed insufficient matches in the comparative database; thus, in more than half the cases, an estimate could not be derived. The preliminary study demonstrated that sex could not be accurately predicted using any of the three methods. However, method #3 consistently returned enough matches (29 of 30) from which to build an estimate for age and race. Although some success was apparent for methods #1 and #2, the most conservative method (#3) was deemed to hold the greatest potential for predicting the biological profile. Therefore, only method #3 was used to predict the age and race for the remaining 60 prescriptions, and all of the following results were derived from this method.

All database searches were conducted using Microsoft Access, and the statistics were computed using SPSS Statistics version 10.0. The databases utilized in this study are available for public use through the web-based search tool OptoSearch, which can be found at the JPAC website (www.jpac.pacom.mil/index.php_) under the tab for the Central Identification Laboratory or directly at www.jpac.pacom.mil/index.php?page=optosearch&size=100&ind=2 (this address may change through time). Individuals can access this website and conduct a query of the database using a complete or partial eyeglass prescription. The website contains a list of instructions, as well as database information.

## Results and Discussion

Estimates of the biological profile for each of the 90 prescriptions were generated and the information was tabulated. Table 1 presents the estimated age and race from method #3 as compared with the biological profile of the known cases. In five instances, estimates could not be generated because of the lack of comparison data, and for three cases, only age estimates were possible (based on bifocal prescriptions). The method correctly predicted the age (±10 years) of the study participants 81.2% of the time (69 of 85 cases); those with bifocal corrections had a 100% success rate. When the number of matches per query is examined, those individuals with greater than ten returned matches were aged correctly 81.3% of the time (52 of 64 cases), as compared to 80.9% aged correctly for those with ten or fewer matches (17 of 21 cases).

Age estimates utilized exact bifocal matches when applicable. Bifocal prescriptions are highly correlated with age ($R = 0.879$, $R^2 = 0.772$, $p = 0.000$) and therefore can make excellent predictors of age (Figure 1). Bifocal corrections typically are not needed until the fourth decade of life; of 884 individuals in the current CILEPI database with bifocal prescriptions, only 20 are less than 40 years of age. Table 2 presents the bifocal prescription data, from +0.75 diopters to +3.0 diopters of correction, and its relationship to age. Of 31 possible age estimates utilizing bifocal prescriptions, all were within ten years of the actual age, with a range of -10 to +9 years. Estimates based on bifocal prescriptions were an average of less than five years different from the actual age (mean = 4.3 years). Sixteen estimates underestimated the age, 12 estimates were older than the actual age, and 3 were correct. Age estimates utilizing bifocal corrections were the most accurate in the study.

As noted, none of the methods were able to accurately predict the sex of the individual. Frequently, the sex estimates performed the same as a coin flip, typically because of the lack of a clearly denoted prevalence in one category. For example, using method #3 for the first 30 cases, sex could not be predicted in 13 cases, was mispredicted in eight cases, and was accurately predicted in nine cases. This results in a 53% accuracy (9 of 17 cases) where sex could be predicted and an overall accuracy of 30% (9 of 30 cases). Although we conclude that sex estimates cannot be reliably predicted from the lenses or prescriptions themselves, we suggest that eyewear frame styles might, in many cases, provide a clue as to the sex of an unknown individual, because frame styles are usually designed to be gender-specific.

Racial estimates also fared poorly. In only 22 of 82 possible cases was the race of the individual correctly predicted, resulting in a 26.8% accuracy rate. This is only slightly greater than chance, given four possible racial categories. For estimates by individual racial category, Whites were 27% correct, Blacks were 15% correct, Hispanics were 47% correct, and Asians were 26% correct. Many racial estimates were based on very close frequency data (e.g., White frequency = 0.0225, Black frequency = 0.0215), which likely led to an incorrect racial assignment. Therefore, we examined those cases that were at least double that of the other racial categories (e.g., White frequency = 0.0526, Black frequency = 0.0215, Hispanic frequency = 0.0123, Asian frequency = 0.0004). In these instances (n=17), the racial estimates were more accurate, at 41.2%, or almost twice what would be expected by chance alone.

## Conclusion

Three different methods were proposed and tested in this paper to determine whether the biological profile (sex, age, and race) of unknown individuals could be accurately predicted based on their eyeglass prescriptions. A composite of two databases was queried to find matching or closely related prescriptions. Two of the methods, methods #1 and #2, failed to reliably predict an accurate biological profile. None of the methods were effective at reliably determining the sex of an individual. The most conservative method, method #3, determined the age (±10 years) of an individual in 81% of the cases, in both young and old age categories. When bifocal prescriptions were present, age (±10 years) was correctly estimated in 100% of the cases. Overall, racial estimates proved to be equal to chance; in cases where one racial estimate was at least twice the frequency of the others, the percentage correct improved to 41%. These results are consistent with at least two other studies that indicate refractive errors are linked with age and possibly race [7, 8].

The findings of this pilot study are important to forensic investigators for several reasons. First, the ability to deduce the age of an unknown individual is a primary goal of the forensic identification process. This method appears to work well, especially in the older age brackets, where more traditional osteological methods are less effective. The age estimates developed from the bifocal prescriptions were particularly effective in predicting the age of those individuals greater than 40 years. Second, determining the age range of an unknown suspect from eyeglass lenses could potentially help law enforcement officials with certain crime scenes. Although rare, cases have been published in which eyewear was a component of criminal investigations [2-5]. Finally, this paper adds support to previous studies [1, 10] that indicate sex and race are difficult to predict from eyewear, principally because of the *uniqueness* of specific refractive errors. Therefore, in cases where prescription eyewear is present, an age range for an unknown individual can be predicted, and once a short list of potential individuals is created, the uniqueness of a given prescription can be used to support a positive identification.

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For further information please contact:

Gregory E. Berg, Ph.D.
Forensic Anthropologist
Joint POW/MIA Accounting Command - Central Identification Lab
310 Worchester Ave.
Hickam AFB, HI 96853
greg.berg@jpac.pacom.mil

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| Glasses or Exam Number | Reported Age | Estimated Age (Mean) | Estimated Age (Range) | Reported Race | Estimated Race |
|---|---|---|---|---|---|
| 1 | 46 | 41 | 31-51 | Black | Hispanic |
| 2 | 27 | 24 | 14-34 | Hispanic | Asian |
| 3 | 35 | 25 | 15-35 | White | Asian |
| 4 | 38 | 23 | 13-33 | Asian | White |
| 5 | 48 | 48 | 45-65 | White | Hispanic |
| 6 | 41 | 38 | 28-48 | Hispanic | Black |
| 7 | 36 | 26 | 16-36 | White | White |
| 8 | 50 | 48 | 38-58 | Black | Hispanic |
| 9 | 47 | 44 | 34-54 | White | Asian |
| 10 | 59 | 52 | 42-62 | White | Black |
| 11 | 46 | 53 | 43-63 | White | White |
| 12 | 26 | 34 | 19-39 | White | White |
| 13 | 34 | 26 | 16-36 | White | Asian |
| 14 | 21 | 30 | 20-40 | White | Asian |
| 15 | 40 | 28 | 18-38 | White | Hispanic |
| 16 | 47 | 42 | 32-52 | White | Hispanic |
| 17 | 45 | 50 | 40-60 | White | Hispanic |
| 18 | 49 | 31 | 21-41 | White | White |
| 19 | 49 | No Est. | No Est. | White | No Est. |
| 20 | 35 | 30 | 20-40 | White | White |
| 21 | 48 | 39 | 29-49 | Asian | White |
| 22 | 38 | 25 | 15-35 | White | Hispanic |
| 23 | 36 | 30 | 20-40 | White | Black |
| 24 | 36 | 29 | 19-39 | White | White |
| 25 | 61 | 60 | 50-70 | White | Hispanic |
| 26 | 34 | 27 | 17-37 | White | Asian |
| 27 | 49 | 36 | 26-46 | White | Hispanic |
| 28 | 47 | 53 | 43-63 | White | White |
| 29 | 34 | 28 | 18-38 | White | Hispanic |
| 30 | 20 | 21 | 11-31 | Asian | Asian |
| 31 | 35 | 40 | 30-50 | White | Hispanic |
| 32 | 46 | 48 | 38-58 | Black | Black |
| 33 | 41 | 27 | 17-37 | White | White |
| 34 | 41 | 23 | 13-33 | Black | White |
| 35 | 26 | 37 | 27-47 | Black | Asian |
| 36 | 33 | 32 | 22-42 | Black | Hispanic |
| 37 | 51 | 60 | 50-70 | Asian | White |
| 38 | 36 | 38 | 28-48 | Hispanic | Hispanic |
| 39 | 45 | 39 | 29-49 | Black | Hispanic |
| 40 | 38 | No Est. | No Est. | Black | No Est. |
| 41 | 25 | 26 | 16-36 | Asian | Asian |
| 42 | 39 | 22 | 12-32 | Black | Asian |
| 43 | 28 | 28 | 18-38 | Asian | Hispanic |
| 44 | 31 | No Est. | No Est. | Black | No Est. |
| 45 | 35 | 26 | 16-36 | Asian | Black |

*Table 1*

*Method 3 estimated and real age and race comparisons.*

| Glasses or Exam Number | Reported Age | Estimated Age (Mean) | Estimated Age (Range) | Reported Race | Estimated Race |
|---|---|---|---|---|---|
| 46 | 64 | 60 | 50-70 | Asian | Black |
| 47 | 44 | 25 | 15-35 | Hispanic | Asian |
| 48 | 29 | 19 | 9-29 | Hispanic | White |
| 49 | 47 | 39 | 29-49 | Black | Black |
| 50 | 55 | 53 | 43-63 | Asian | White |
| 51 | 31 | No Est. | No Est. | Hispanic | No Est. |
| 52 | 29 | 30 | 20-40 | Black | Hispanic |
| 53 | 59 | 53 | 43-63 | Black | No Est. |
| 54 | 39 | 22 | 12-32 | Asian | Asian |
| 55 | 45 | 39 | 29-49 | Asian | Hispanic |
| 56 | 51 | 53 | 43-63 | Hispanic | Asian |
| 57 | 24 | 30 | 20-40 | Black | Black |
| 58 | 66 | 66 | 56-76 | Hispanic | Black |
| 59 | 38 | 44 | 34-54 | Black | White |
| 60 | 39 | 27 | 17-37 | Black | White |
| 61 | 32 | 28 | 18-38 | Black | Hipanic |
| 62 | 56 | 60 | 50-70 | Asian | No Est. |
| 63 | 57 | 66 | 56-76 | Black | Hispanic |
| 64 | 20 | 31 | 21-41 | Hispanic | Hispanic |
| 65 | 20 | 33 | 23-43 | Asian | Black |
| 66 | 76 | 66 | 56-76 | Black | Black |
| 67 | 39 | 31 | 21-41 | Black | Hispanic |
| 68 | 49 | 53 | 43-63 | Asian | Black |
| 69 | 34 | 30 | 20-40 | Asian | Black |
| 70 | 59 | 53 | 43-63 | Asian | No Est. |
| 71 | 34 | No Est. | No Est. | Hipanic | No Est. |
| 72 | 40 | 22 | 12-32 | Hispanic | Asian |
| 73 | 43 | 29 | 19-39 | Asian | Asian |
| 74 | 21 | 22 | 12-32 | Hispanic | Hispanic |
| 75 | 41 | 24 | 14-34 | Black | Asian |
| 76 | 24 | 29 | 19-39 | Black | White |
| 77 | 42 | 39 | 29-49 | Hispanic | Hispanic |
| 78 | 30 | No Est. | No Est. | Hispanic | No Est. |
| 79 | 20 | 27 | 17-37 | Black | White |
| 80 | 41 | 39 | 29-49 | Asian | White |
| 81 | 50 | 45 | 35-55 | Hispanic | Hispanic |
| 82 | 64 | 60 | 50-70 | Asian | Black |
| 83 | 52 | 60 | 50-70 | Hispanic | Hispanic |
| 84 | 47 | 44 | 34-54 | Hispanic | Hispanic |
| 85 | 35 | 29 | 19-39 | Black | Black |
| 86 | 21 | 28 | 18-38 | Black | Asian |
| 87 | 19 | 25 | 15-35 | Hispanic | Asian |
| 88 | 44 | 44 | 34-54 | Asian | Asian |
| 89 | 31 | 33 | 23-43 | Hispanic | Hispanic |
| 90 | 40 | 37 | 27-47 | White | Hipanic |

*Table 1 (continued)*

| Bifocal strength (diopters) | n | Mean Age (in years) | Standard Deviation (in years) |
|---|---|---|---|
| +0.75 | 8 | 39.88 | 2.80 |
| +1.00 | 34 | 39.11 | 5.35 |
| +1.25 | 49 | 43.53 | 2.21 |
| +1.50 | 65 | 44.86 | 4.77 |
| +1.75 | 81 | 47.56 | 5.24 |
| +2.00 | 108 | 53.11 | 6.16 |
| +2.25 | 208 | 59.95 | 7.70 |
| +2.50 | 259 | 65.55 | 8.07 |
| +2.75 | 51 | 70.49 | 7.15 |
| +3.00 | 21 | 75.00 | 7.81 |

*Table 2*

*Bifocal strength and the mean predicted age for the CILEPI database.*

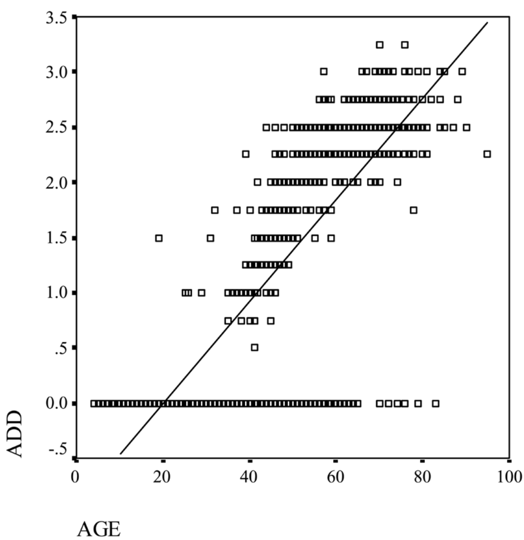


*Figure 1*

*Scatter plot of age and bifocal strength. Plotted regression line has an $R^2$ value of 0.772. ADD refers to the bifocal prescription strength.*