

Revue scientifique
Faculté de Médecine de Nouakchott
Mauritanie

MAURITANIE MÉDICALE

Article Original

Analyzing the location of glaucomatous visual field defects using first, second and third order moments.

Analyse de l'emplacement des défauts du champ visuel glaucomateux en utilisant les moments mathématiques du premier, deuxième et troisième ordre.

Auteurs :
Chunwei Zhang[1], Andrew J. Tatham[2]

Auteur correspondant : Chunwei Zhang, Associete Professor Ophtalmology
E-mail : zcw1229@163.com ; andrewjtatham@gmail.com

Affiliation des auteurs :
[1] Department of Ophthalmology, the First Affiliated Hospital, Harbin Medical University, Harbin, China.)
[2] Princess Alexandra Eye Pavilion and Department of Ophthalmology, University of Edinburgh, UK.

Supported in part by Natural Science Foundation of Heilongjiang Province for Returned Scholars, China. No.LC2012C21 (C.Z.); Innovation research special fund of the Science and Technology of Harbin of Heilong Jiang Province, China. No.2011RFLYS029 (C.Z.). Research fund of the First Affiliated Hospital of Harbin Medical University, China No.2007021(C.Z.). Scientific and technical research fund of Education Bureau of Heilongjiang Province, China. No.12511311 (C.Z.).

Article Info

Soumis : le 03/07/2017
Accepté : le 06/12/2017

Abstract

Purpose :

To assess whether measuring the moments of a visual field has utility in describing the location and shape of visual field loss.

Methods :

This was a cross-sectional study involving participants from a prospective longitudinal study designed to evaluate optic nerve structure and visual function in glaucoma. The study involved the analysis of SAP results for 180 eyes of 107 subjects with a mean age of 61.6 ± 16.8 years, including 90 glaucomatous eyes of 60 subjects and 90 healthy eyes of 47 subjects. SAP testing was performed using the SITA Standard 24-2 strategy of the Humphrey visual field analyzer. The initial step in calculating the moments of the visual field was to convert the threshold values into linear units. All statistical analyses were performed with commercially available software (STATA, version 12; StataCorp LP.

Results :

The glaucomatous eyes had an average MD of -5.8 ± 6.6dB (range -25.4 to 1.2dB) compared to 0.3 ± 0.8 dB (range -1.0 to 2.5dB) in healthy eyes. The coordinates of the center of mass of threshold values (remaining visual field) and the center of visual field defects were calculated using the first moment .The coordinates of the center of visual field defects showed good correspondence to the location of the visual field defect seen on the SAP total deviation map. In each case the first moment coordinates show a good spatial relationship to the defect. There was reasonable agreement between the average coordinates for the center of remaining vision assigned by the graders and the first moment. There was also reasonable agreement between the average coordinates for the center of the visual field defect assigned by the graders and the first moment. The second moment has been proposed as a measure of the centrality of visual field defect it is strongly affected by disease severity. There was a similar relationship between the third and fourth moments, disease severity and the presence or

absence of central defects as that found for the second order moment.

Conclusion :

The first moments of visual field thresholds and deviation values are useful objective measures of the shape of the hill of vision.

Keywords : Deviation value • Visual field • the first order moment • Glaucoma.

Résumé

Objectif :

Déterminer si la mesure des moments d'un champ visuel ont une utilité dans la description de l'emplacement et la forme dans les déficits du champ visuel.

Méthodes:

Cette étude est transversale avec des participants tirés à partir d'une étude prospective longitudinale conçue pour évaluer la structure de nerf optique et la fonction visuelle en fonction du glaucome. L'étude a porté sur l'analyse des résultats SAP pour 180 yeux de 107 sujets avec un âge moyen de 61,6 ± 16,8 années, 90 yeux glaucomateux de 60 sujets et 90 yeux sains de 47 sujets. ce test SAP a été réalisé en utilisant la stratégie standard SITA 24-2 de l'analyseur de champ visuel Humphrey. La première étape dans le calcul des moments de champ visuel est de convertir les valeurs en unités linéaires de seuil. Toutes les analyses statistiques ont été réalisées avec des logiciels disponibles dans le commerce (STATA, la version 12; StataCorp LP)

Résultats:

Les yeux glaucomateux avaient une moyenne de -5,8 ± 6,6 dB MD (plage -25,4 à 1.2dB) à 0,3 ± 0,8 dB par rapport (plage de -1,0 à 2,5 dB) dans la santé des yeux. Les coordonnées du centre de masse de valeurs de seuil (restantes champ visuel) et le centre de défauts du champ visuel ont été calculés en utilisant le premier instant coordonnées du centre. Procédé de défauts du champ visuel a montré une bonne correspondance avec l'emplacement de l'anomalie du champ visuel vu SAP total d'écart sur la carte. Dans chaque cas, le premier moment les coordonnées montrent une bonne relation spatiale au défaut. Il y avait un accord raisonnable entre les coordonnées moyennes pour le centre de vision restant Assigné par les élèves et le premier moment. Il y avait un accord raisonnable aussi entre les coordonnées moyennes pour le centre du défaut du champ visuel affecté par les élèves et le premier moment. Le deuxième moment a été proposé comme une mesure de la centralité du défaut du champ visuel, il est fortement influencé par la gravité de la maladie. Il y avait une relation comme entre les troisième et quatrième moments, la gravité de la maladie et la présence ou l'absence de défauts du centre que l'on trouve pour le deuxième moment.

Conclusion :

Les premiers instants de seuils et valeurs d'écart champ visuel sont des mesures objectives utiles de la forme de la colline de la vision.

Mots clés : valeur de déviation • Champ visuel • le moment du premier ordre • Glaucome.

الملخص

تحليل موقع عيوب المجال البصري فى الزرق باستخدام خصائص اللحظات الرياضية الأولى والثانية والثالثة

الغرض: تقييم ما إذا كان قياس لحظات من المجال البصري لها فائدة في وصف المكان وشكل

Article original

فقدان البصر.
الطرق: وكانت هذه الدراسة مستعرضة و بمشاركين من دراسة استطلاعية طولية تهدف إلى تقييم العصب البصري وبنية البصرية في وظيفة الزرق. وشملت الدراسة تحليل النتائج SAP ل 180 عين ل 107 شخص مع متوسط أعمارهم 61.6 ± 16.8 سنة، 90 عين زرقية ل 60 شخص و 90 عين ل 47شخص اصحاء. تم إجراء اختبار SAP باستخدام استراتيجية SITA معيار محلل المجال البصري همفري 24-2. وكانت الخطوة الأولى في حساب لحظات من المجال البصري لتحويل القيم إلى وحدات عتبة الخطية. كل التحليلات الإحصائية أجريت مع البرمجيات المتاحة تجاريا (STATA، الإصدار 12؛ StataCorp LP)

النتائج: عيون زرقية كان في المتوسط -5.8 ± 6.6dB MD (المدى -25.4 إلى 1.2dB) إلى 0.3 ± 0.8 مقارنة ديسيبل (مجموعة -1.0 إلى 2.5dB) في عيون صحية. إحداثيات مركز الكتلة من قيم العتبة (المتبقية المجال البصري) ومركز عيوب المجال البصري حسبت باستخدام اللحظة الأولى إحداثيات مركز. والعيوب المجال البصري وأظهرت المراسلات جيدة إلى موقع الخلل المجال البصري ينظر إجمالي SAP الانحراف على الخريطة. في كل حالة تنسق اللحظة الأولى تظهر العلاقة المكانية جيدة لعيب. وكان هناك اتفاق معقول بين متوسط إحداثيات مركز الرؤية المتبقية المخصصة من قبل طلاب الصف ومنذ اللحظة الأولى. وكان هناك اتفاق معقول أيضا بين متوسط إحداثيات مركز عيب المجال البصري المخصصة من قبل طلاب الصف ومنذ اللحظة الأولى. لحظة الثانية وقد اقترح كمقياس للمركزية عيب المجال البصري يتأثر بشدة من شدة المرض. كانت هناك علاقة بين مثل لحظات الثالثة والرابعة، شدة المرض ووجود أو عدم وجود عيوب المركز كما وجدت لثانية وهذا أمر حظة.
الاستنتاجات: إن اللحظات الأولى من عتبات المجال البصري والقيم الانحراف هي التدابير الموضوعية مفيدة من شكل تلة الرؤية.

كلمات البحث: قيمة الانحراف • المجال البصري • أول لحظة النظام • الزرق

Introduction

Glaucomatous visual field loss is a significant cause of morbidity and impaired quality of life.[1-3] For example, patients with visual impairment due to glaucoma often limit activities due to fear of falling.[3,4] Visual field loss has also been associated with an increased risk of involvement in motor vehicle collisions.[5,6] As morbidity associated with glaucoma increases with worsening disease, it is important that disease severity is appropriately evaluated. The severity of functional loss can be assessed using standard automated perimetry (SAP) and SAP global indices such as mean deviation (MD) and pattern standard deviation (PSD), measured in decibels, can be useful summary indicators of the stage of disease. However, in addition to severity, the location of visual field loss is also likely to be an important factor affecting the impact of glaucoma on day-to-day activities. Specifically central defects are likely to be of greater significance than peripheral, and inferior defects may affect the ability to perform tasks differently to superior defects.[4,7]

The pattern and extent of visual field defects can be characterized by simple inspection of the SAP printout and the use of grading schemes, such as that of the Ocular Hypertension Treatment Study (OHTS).[8] The OHTS Study Group classified visual field loss by shape and location for each superior and inferior hemifield using categories such as altitudinal, arcuate, partial arcuate, nasal step, paracentral and temporal wedge. These terms are widely used in clinical practice; however classification schemes are somewhat subjective, require a trained observer, and even in the OHTS, following adjudication, 3 graders agreed on classification only 70% of the time.[8] An objective quantitative method for assessing the location and pattern of visual field defects would be advantageous.

Recently it has been proposed that the moments of linear scale threshold values can be used to describe the location and distribution of visual field loss (Boland MV, et al. IOVS 2013:ARVO E-Abstract 4015). Moments are used in mathematics as quantitative measures of the shape of a set of points and therefore could be useful as a measure of the shape of the hill of vision. The first moment of a discrete set of measures is analogous to the center of mass of the system.[9] In a two-dimensional system the coordinates of the center of mass are determined along the horizontal and vertical axes. Therefore the first moment along the vertical axis could be used as a measure of superior or inferior visual field loss, i.e., whether the center of the remaining visual field is shifted superiorly or inferiorly.

Higher order moments (second, third and fourth moments) represent other aspects of the distribution of points. The second moment is a measure of the variance of the points; the third moment is a measure of skewness, and the fourth moment a measure of kurtosis.[9] It has been suggested that the second moment along the horizontal axis may be used as measure of central or peripheral field loss (Boland MV, et al. IOVS 2013:ARVO E-Abstract 4015). The aim of the current study was to assess whether measuring the moments of a visual field has utility in describing the location and shape of visual field loss.

Methods

Study Participants

This was a cross-sectional study involving participants from a prospective longitudinal study designed to evaluate optic nerve structure and visual function in glaucoma; the Diagnostic Innovations in Glaucoma Study (DIGS) at the University of California, San Diego (UCSD). Methodological details have been described previously.[10] Informed consent was obtained from all the participants, and the institutional review board approved all methods. All methods adhered to the tenets of the Declaration of Helsinki for research involving human subjects and the study was Health Insurance Portability and Accountability Act (HIPAA) compliant.

At each visit subjects underwent a comprehensive ophthalmologic examination including visual acuity, slit-lamp biomicroscopy, intraocular pressure (IOP) measurement, gonioscopy, dilated fundoscopic examination, simultaneous stereoscopic optic disc photography, and SAP using the Swedish interactive threshold algorithm (SITA Standard 24-2). Only subjects with open angles on gonioscopy were included. Subjects were excluded if they presented with a best-corrected visual acuity less than 20/40, spherical refraction outside ±5.0 diopters and/or cylinder correction outside 3.0 diopters, or any other ocular or systemic disease that could affect the optic nerve or the visual field. Eyes were classified as glaucomatous if they had repeatable (≥2 consecutive) abnormal SAP test results and an abnormal SAP result was defined by a pattern standard deviation outside the 95% confidence limits or a glaucoma hemifield test result outside the reference range. Healthy subjects were recruited from the general population through advertisements and from the staff and employees of UCSD. Healthy eyes had IOP less than 22 mmHg with no history of increased IOP and normal SAP. The present study involved the analysis of SAP results for 180 eyes of 107 subjects, including 90 glaucomatous eyes of 60 subjects and 90 healthy eyes of 47 subjects.

Standard Automated Perimetry

SAP testing was performed using the SITA Standard 24-2 strategy of the Humphrey visual field analyzer (Carl Zeiss Meditec, Inc.). All visual fields were evaluated by the UCSD Visual Field Assessment Center (VisFACT).[11] Visual fields with more than 33% fixation losses or false-negative errors, or more than 15% false-positive errors, were excluded. The only exception was the inclusion of fields with false-negative errors of more than 33% when the field showed advanced disease. Visual fields exhibiting a learning effect (i.e., initial tests showing consistent improvement on visual field indices) were also excluded. Visual fields were further reviewed for the following artifacts : eyelid and rim artifacts, fatigue effects, inappropriate fixation, evidence that the visual field results were caused by a disease other than glaucoma and inattention.

Following VisFACT assessment, 2 ophthalmologists with subspecialist glaucoma training independently marked on the total deviation plot the

locations deemed to correspond to the center of the visual field defect and the center of remaining vision for each visual field. The graders were masked to the moment calculations. The co-ordinates for the points assigned by the graders were then compared to the first order moments calculated using commercially available software (STATA, version 12; StataCorp LP). Visual fields were classified as having a central defect if at least one point, of a cluster of at least 3 contiguous points with P-values of <5% on the total deviation probability map, involved the central 5 degrees, or if at least one point, of a cluster of at least 2 contiguous points with P-values of <0.5%, was within the central 5 degrees.

Calculation of moments

The initial step in calculating the moments of the visual field was to convert the threshold values into linear units. A decibel is 10 times the log of the reciprocal of stimulus intensity measured in Lamberts (L) [i.e., dB = 10*log (1/L)] and therefore 0 dB converted to 1.0 and 30 dB to 1000. The first moment about the y-axis (M_y) of n visual field threshold values located at points (x1, y1), (x2, y2),..... (xn, yn) can be defined as:

$$M_y = \sum_{i=1}^{n} m_i x_i$$

Where mi is the linear threshold value located at point xi on the horizontal axis. The nasal visual field locations (at 3, 9, 15, 21 and 27 degrees) were deemed positive and the temporal visual field locations were deemed negative. Similarly the superior field locations were assigned positive locations and the inferior negative. The first moment of the threshold values about the x-axis (M_x) was calculated as:

$$M_x = \sum_{i=1}^{n} m_i y_i$$

Where mi is the linear threshold value located at point yi on the vertical axis. The first order moment, or coordinate of the center of mass of the remaining visual field was therefore:

$$\left(\frac{M_y}{M}, \frac{M_X}{M}\right)$$

Where M is the sum of all linear threshold values:

$$M = \sum_{i=1}^{n} m_i$$

The center of mass along the vertical axis was used to determine whether the visual field had shifted superiorly or inferiorly, i.e., whether the visual field defect was predominantly inferior or superior. The center of mass of the visual field defect itself was calculated using the total deviation figures. The second order moments were calculated by taking a shifted average of the squares along the vertical and horizontal axes using the follow formulas:

$$Second\ moment_y = \frac{\sum(M_{yi} - \overline{M_y})^2}{n-1}$$

$$Second\ moment_x = \frac{\sum(M_{xi} - \overline{M_x})^2}{n-1}$$

The second moments were divided by 106 for ease of further analysis. The third and fourth order moments were similarly calculated along the vertical and horizontal axes using the above formula but by raising values to the third and fourth power respectively. An example of the method of calculation of the moments is shown in Figure 1.

Statistical Analysis

Normality assumption was assessed using Shapiro-Wilk tests and by inspection of histograms. Student t-tests were used for group comparison for normally distributed variables and Wilcoxon rank-sum test for continuous non-normal variables. The inter-observer agreement for the coordinates of the center of remaining visual field assigned by the two graders was assessed using the concordance correlation coefficient (rho c), with the horizontal and vertical axes examined separately.[12,13] The inter-observer agreement regarding the coordinates of the center of visual field defects was similarly assessed, as was the agreement between the average coordinates assigned by graders and the coordinates obtained from the first moment. The concordance correlation coefficient combines measures of precision and accuracy to determine the

deviation of the observed data from the line of perfect concordance, with a value of -1 corresponding to perfect negative agreement, a value of +1 corresponding to perfect positive agreement and a rho c of 0 indicating no agreement.[14]

The second moments in eyes with a central field defect were compared to the second moments in eyes without a central field defect. The association between the second moment and the centrality of the visual field defect was investigated using a univariate logistic model, followed by a multivariate logistic analysis to take into account the effect of disease severity. All statistical analyses were performed with commercially available software (STATA, version 12; StataCorp LP). The α level (type I error) was set at 0.05.

Results

The study included 180 eyes of 107 subjects with a mean age of 61.6 ± 16.8 years. There were 90 healthy eyes of 47 subjects and 90 glaucomatous eyes of 60 subjects. The glaucomatous eyes had an average MD of -5.8 ± 6.6dB (range -25.4 to 1.2dB) compared to 0.3 ± 0.8 dB (range -1.0 to 2.5dB) in healthy eyes.

First moment

The coordinates of the center of mass of threshold values (remaining visual field) were calculated using the first moment and are plotted in Figures 2A and 2B for healthy and glaucomatous eyes respectively. The mean center of the healthy eye visual fields was located 1.1 degrees inferiorly (ranging from 3.2 degrees inferiorly to 0.7 degrees superiorly) and 1.1 degrees nasally (ranging from 0.7 degrees temporally to 3.9 degrees nasally). Glaucomatous eyes frequently had a center of remaining field outside this range. The center of remaining field in glaucomatous eyes ranged from 9.6 degrees inferiorly to 6.1 degrees superiorly, and from 18.0 degrees nasally to 4.3 degrees temporally.

The coordinates of the center of visual field defects were also calculated using the first moment of total deviation values and are shown in Figure 3. The coordinates of the center of visual field defects showed good correspondence to the location of the visual field defect seen on the SAP total deviation map. Figure 4 shows examples of eyes with an inferior nasal step (Figure 4A), superior altitudinal defect (Figure 4B) and central defect (Figure 4C). In each case the first moment coordinates show a good spatial relationship to the defect. For example, in the presence of a superior visual field defect, the first moment correctly identified that the center of the visual field defect was located superiorly and that the remaining visual field had shifted inferiorly (Figure 4B).

The first moments were compared to the average coordinates of the center of remaining vision and the center of the visual field defect recorded by the graders. There was reasonable agreement between the average coordinates for the center of remaining vision assigned by the graders and the first moment (rho c for x-axis coordinates =0.60, 95% CI 0.48 to 0.71; rho c for y-axis coordinates =0.55, 95% CI 0.45 to 0.66). In 69 of 90 glaucomatous eyes (77%) the average location of the center of remaining vision assigned by the graders was within 5 degrees of the first moment compared to 66 of 90 eyes (73%) for the y-axis location. There was also reasonable agreement between the average coordinates for the center of the visual field defect assigned by the graders and the first moment (rho c for x-axis coordinates =0.65, 95% CI 0.51 to 0.78; rho c for y-axis coordinates =0.60, 95% CI 0.46 to 0.74). In 68 of 90 glaucomatous eyes (76%) the average location of the center of the field defect assigned by the graders was within 5 degrees of the first moment along both the horizontal and vertical axes. The first order moment indicated 25 glaucomatous eyes had a superiorly located center of remaining visual field. Twenty-four of these eyes (96%) were also identified as having a superiorly located center of vision by the graders. The first order moment indicated 65 glaucomatous eyes had an inferiorly located center of remaining vision. Sixty-three of 65 (97%) were also identified as having an inferiorly located center of vision by the graders. Three of the 90 glaucomatous eyes had a center of mass of remaining vision graded at zero on the y-axis, i.e. the remaining visual field was deemed not to have shifted superiorly or inferiorly.

The inter-observer agreement between graders for determining the center of remaining visual field was poor for the horizontal axis (rho c = 0.39, 95% CI 0.22 to 0.57) but better for the vertical axis coor-

dinates (rho c = 0.86, 95% CI 0.81 to 0.91). The inter-observer concordance correlation coefficients for the location of the center of the field defect was also better for the vertical axis (rho c for x-axis coordinates = 0.58, 95% CI 0.43 to 0.72 versus rho c for y-axis coordinates =0.90, 95% CI 0.86 to 0.94).

Second moment

It has been suggested that the second moment along the horizontal axis, which is a measure of variance, may be a useful measure of the centrality of a visual field defect (Boland MV, et al. IOVS 2013:ARVO E-Abstract 4015). We found that the second moment along the horizontal axis was significantly smaller in glaucomatous compared to healthy eyes and was lower in eyes with central field defects compared to those without (Figure 5). The median (interquartile range) x-axis second moment was 4.7 (2.0 to 8.9) in glaucomatous eyes compared to 26.1 (17.6 to 39.7) in healthy eyes (P<0.001). The second moment along the vertical axis was also significantly smaller in glaucomatous eyes with a median of 3.1 (1.4 to 7.2) compared to 21.6 (14.4 to 30.4) in healthy eyes (P<0.001). The second moment was 2.8 (1.6 to 5.3) and 5.2 (1.9 to 8.6) along the x- and y-axes respectively in eyes with central field defects compared to 6.4 (2.7 to 11.7; P =0.008) and 1.9 (0.9 to 3.9; P =0.001) along the x- and y-axes in glaucomatous eyes without central field defects. Univariate logistic regression analysis revealed a significant association between the second moment along the horizontal axis and the presence of a visual field defect involving the central 5 degrees (odds ratio [OR] =0.92 per unit increase in second moment, P =0.039).

The finding of a smaller second moment in eyes with central defects is contrary to the example calculations in Figure 1, which suggest that eyes with central visual field defects are likely to have higher second moments. A possible explanation is that eyes with central visual field defects may have more severe disease and reduced variance due to a generalized reduction in sensitivity. Therefore it was important to evaluate the relationship between the second moment and disease severity. Figure 6 shows that there was a decrease in the second moment with increasing disease severity (measured by SAP MD) and when MD (converted to linear units) was included in a multivariate model the second moment was no longer indicative of the presence or absence of a central defect (OR =1.04, P =0.40). Therefore although the second moment provides information regarding the distribution of visual field sensitivity, it has limitations as a measure of the centrality of a visual field defect. This is illustrated in Figure 4, which shows that an eye with a central defect but relatively preserved MD (Figure 4C) has a high second moment, but as MD decreases, even in the presence of a central defect the second moment is low (Figure 4B). Similar results were found when the same analysis was performed using the second moment along the vertical axis.

Third and Fourth moments

The third and fourth moments, which are measures of skewness and kurtosis respectively, were calculated for the horizontal and vertical axes and examined using the same method as above. There was a similar relationship between the third and fourth moments, disease severity and the presence or absence of central defects as that found for the second order moment.

Discussion

In this study we have demonstrated that the first moments of visual field sensitivity thresholds can be used to determine the center of mass of the remaining visual field. Similarly, the first moments of total or pattern deviation values can be used to determine the center of mass of a visual field defect. The calculation of first moment coordinates has several possible applications. One application would be to use the first moment along the vertical axis to calculate whether there has been a superior or inferior shift in remaining vision. Whether a visual field defect is predominantly superior or inferior could have important implications for a patient's ability to perform certain tasks, and therefore be a useful marker of how glaucomatous field loss is likely to affect quality of life. Similarly the first moment along the horizontal axis could be used to look for nasal or temporal shift in field. The first moments therefore provide an objective measure of the hill of vision that could be automatically calculated and potentially incorporated into visual field software. The center

of a visual field defect and remaining visual field can also be estimated by trained observers, however, we found there was often poor correlation between observers. In this study inter-observer agreement was higher for measures along the vertical axis than horizontal axis, however, this is probably due to there being less variation in center of mass locations along the vertical axis in this sample.

The calculation of the center of a visual field defect using the first moment has some limitations, for example, in eyes with concentric field loss the center of mass of the field defect may be in a region of normal field. Figure 4D shows an eye with a concentric loss of visual field where the center of the visual field defect calculated by the first moment is located in a relatively preserved region of field, close to the center of mass of remaining field. In such a case, one approach would be to calculate the moments of the visual field for each hemifield separately in a similar way to how visual field defects in the OHTS study were classified by hemifield.8 However, field losses could be symmetrical within a hemifield meaning the center of mass of the defect could still occur in a region of normal field. Furthermore in an eye with symmetrical field loss the first moment of remaining field along the vertical axis will identify that there is neither a superior or inferior shift in remaining vision (Figure 4D), which may be the primary parameter of interest.

Higher order moments measure other characteristics of the distribution of visual field thresholds, for example variance, skewness and kurtosis. The second moment is a measure of variance and we found that eyes with central visual field defects with relative preservation of the remaining visual field have high second moments compared to eyes with isolated peripheral defects. Despite this observation, the highest second moments are in healthy eyes and the second moment decreases with increasing disease severity. The relationship between the second moment and disease severity is to be expected, given that variance will decrease in the presence of a generalized decrease in sensitivity. For example in Figure 4A the x-axis second moment was 4.8 in an eye with a central defect and MD of only -0.37dB compared to an x-axis second moment of 11.4 in an eye with a similar MD but a peripheral defect (Figure 4C). Although the eye in Figure 4B also has a central defect, the MD was -13dB and the second moment only 2.0 due to the severe generalized depression of the superior visual field. The result is that the second moment is more a marker of severity than a useful measure for detecting the centrality of visual field defects.

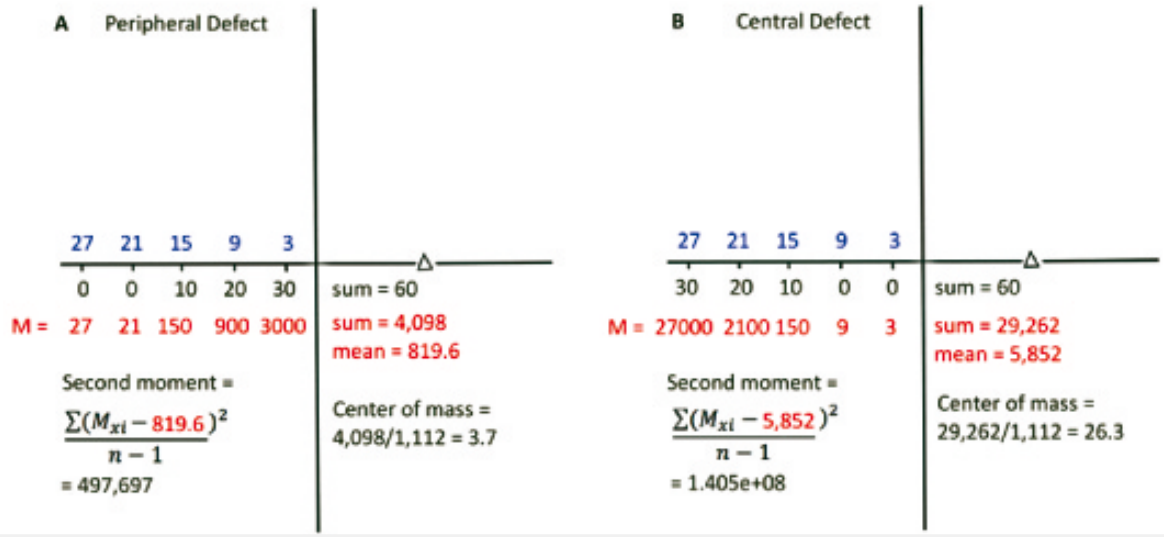


Figure 1 : Method of calculation of first and second moments along the horizontal axis for 5 test points in the nasal field of a right eye. Arbitrary threshold values for points located at 3 to 27 degrees on the horizontal axis are shown for an eye with a peripheral defect (inferior nasal step) (A) and a central defect (B). The second moment is higher in the eye with the central defect. Blue values = horizontal axis co-ordinates, black values = arbitrary thresholds (in decibels), red values = linear moments (M).

Article original

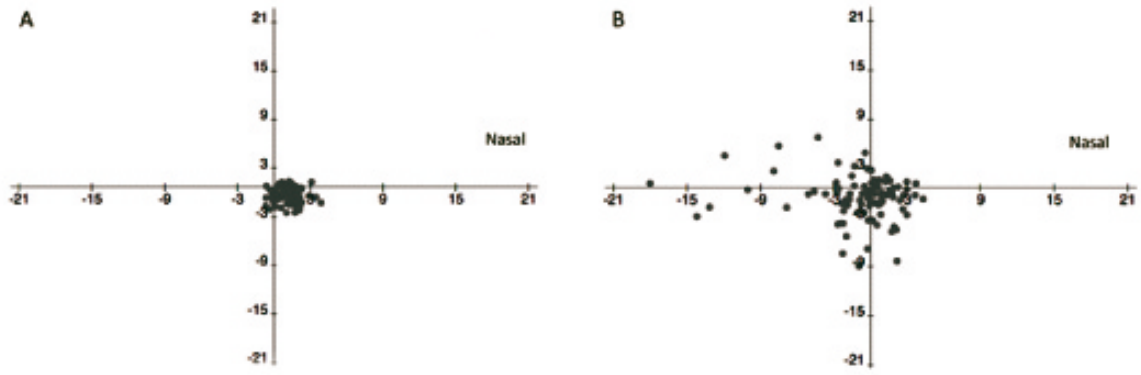


Figure 2 : Coordinates of center of mass (first moment) of remaining visual field in healthy (A) and glaucomatous (B) eyes.

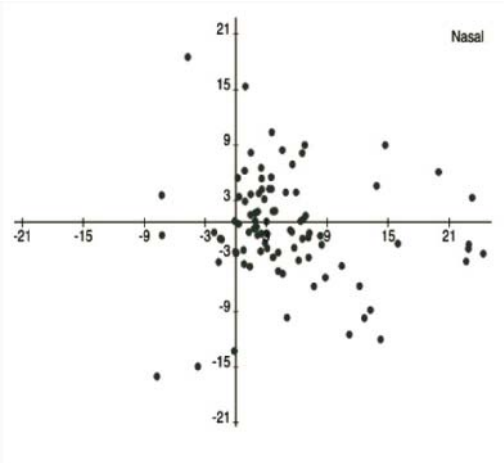


Figure 3 : Coordinates of center of mass (first moment) of visual field defects in glaucomatous eyes.

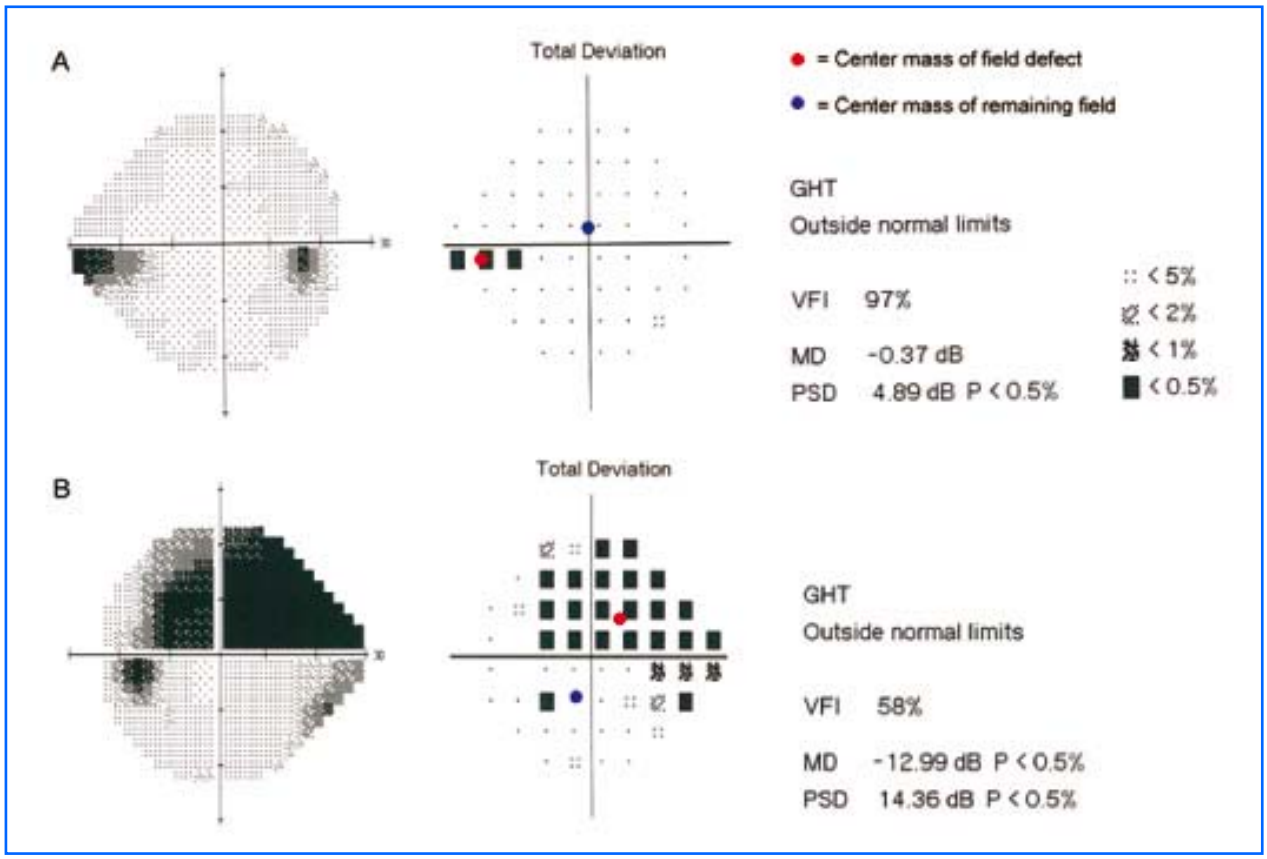


Figure 4 - A & B :

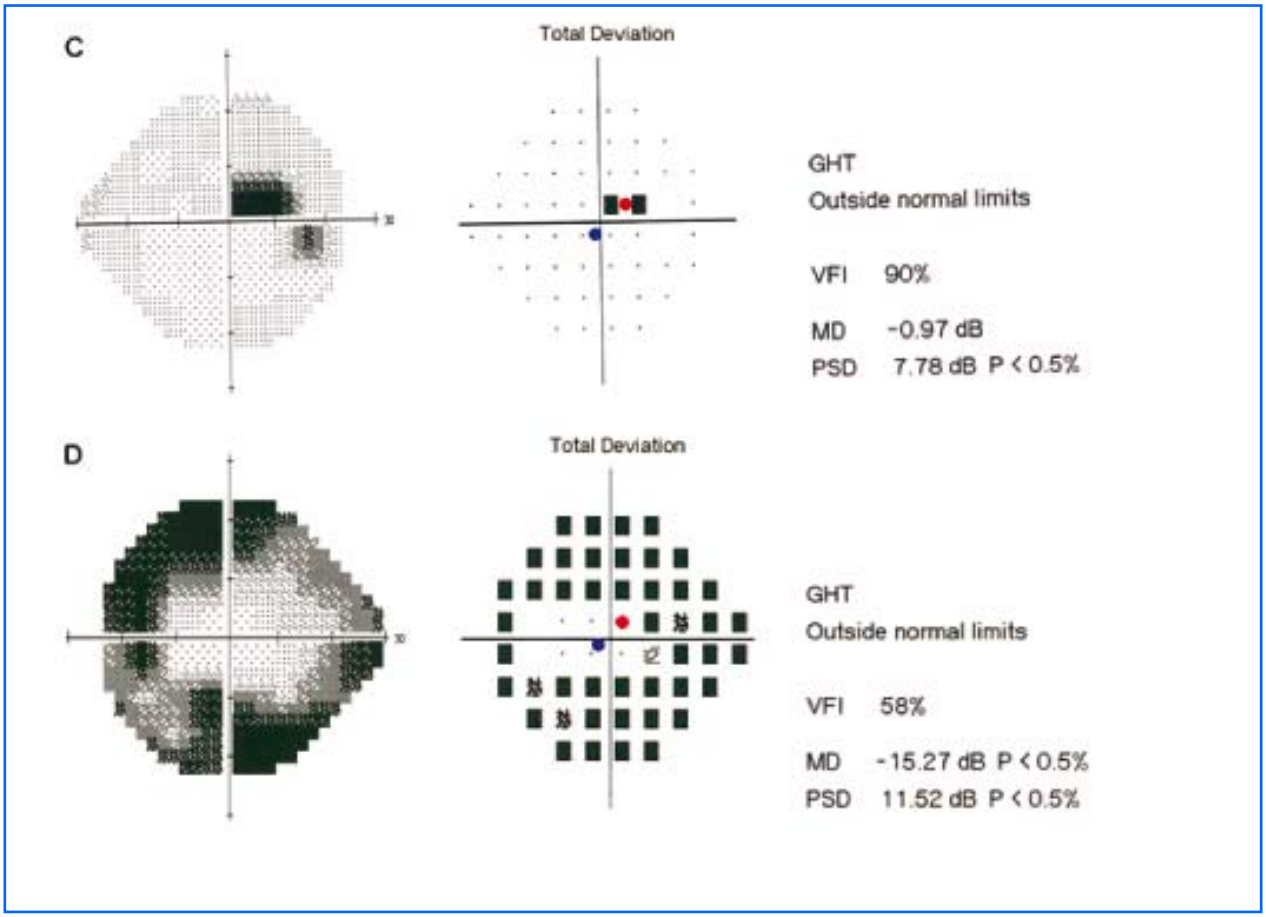


Figure 4 - C & D: Examples of center of mass (first moments) of visual field defect and center of mass of remaining visual field for four eyes included in the study. The second moments for these eyes were 4.8, 2.0, 11.4 and 0.3 respectively.

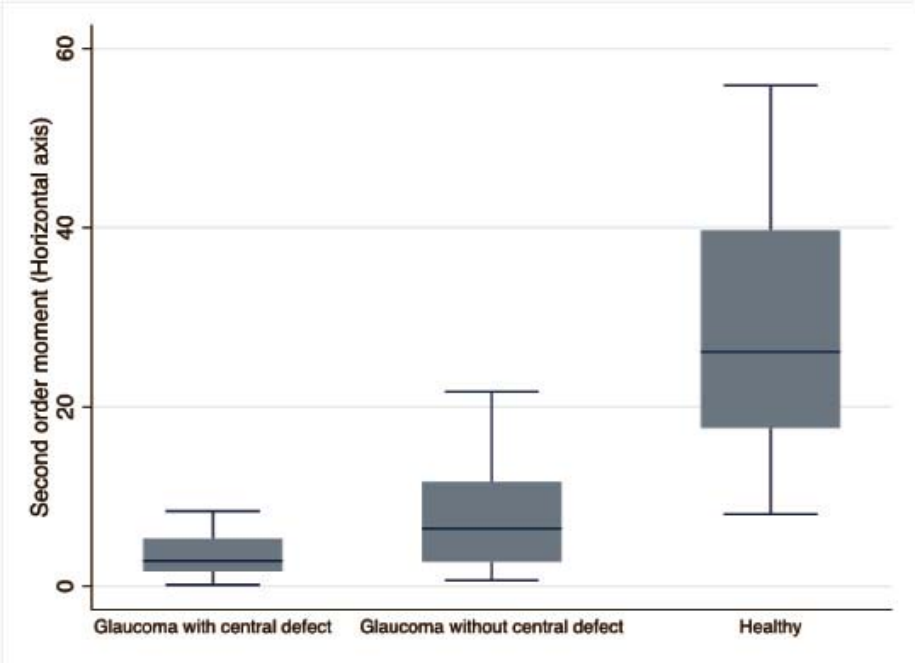


Figure 5 : Box plot showing distribution of second order moment along the horizontal axis in healthy eyes and in glaucomatous eyes with and without a visual field defect involving the central 5 degrees.

Article original

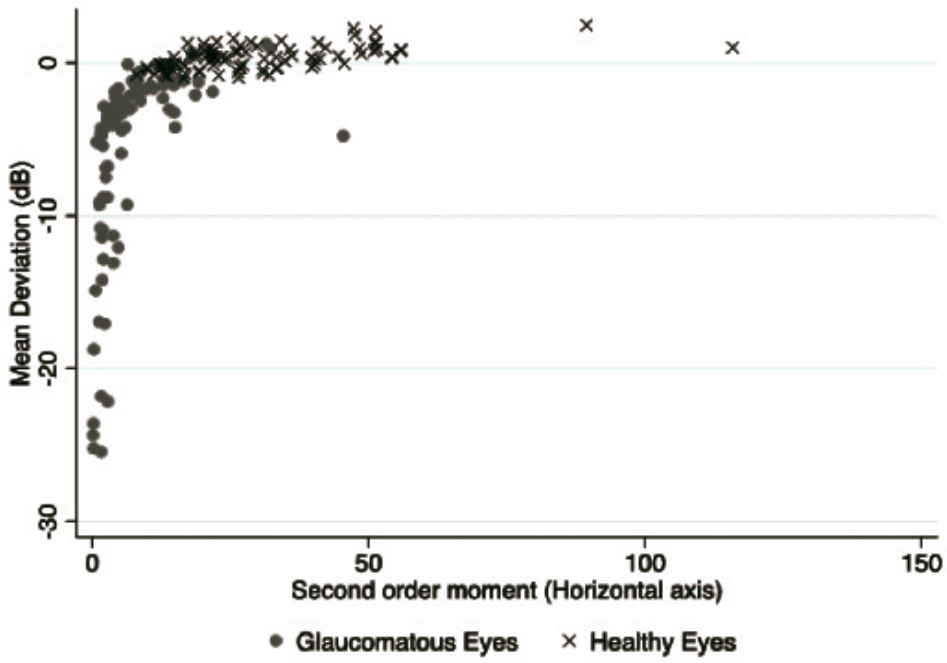


Figure 6 :Scatter plot showing the relationship between mean deviation (in decibels) and the second order moment along the horizontal axis in healthy and glaucomatous eyes.

Conclusion

In conclusion, the present study indicates that the first moments of visual field thresholds and deviation values are useful objective measures of the shape of the hill of vision. Further studies are warranted to investigate the relationship between the first moment-derived location of the center of remaining visual field and quality of life, and the first moment-derived location of the center of remaining visual field and the ability to preform tasks such as driving. In contrast, although the second moment has been proposed as a measure of the centrality of visual field defect it is strongly affected by disease severity, which limits its usefulness.

Références

[1]. Lisboa R, Chun YS, Zangwill LM, et al. Association between rates of binocular visual field loss and vision-related quality of life in patients with glaucoma. JAMA Ophthalmol. 2013; 131:486-494.

[2]. McKean-Cowdin R, Wang Y, Wu J, et al. Impact of visual field loss on health-related quality of life in glaucoma: the Los Angeles Latino Eye Study. Ophthalmology. 2008; 115:941-948.e1.

[3]. Wang MY, Rousseau J, Boisjoly H, et al. Activity limitation due to a fear of falling in older adults with eye disease. Invest Ophthalmol Vis Sci. 2012; 53:7967-7972.

[4]. Black AA, Wood JM, Lovie-Kitchin JE. Inferior field loss increases rate of falls in older adults with glaucoma. Optom Vis Sci. 2011; 88:1275-1282.

[5]. Haymes SA, Leblanc RP, Nicolela MT, et al. Risk of falls and motor vehicle collisions in glaucoma. Invest Ophthalmol Vis Sci. 2007; 48:1149-1155.

[6]. McGwin G, Xie A, Mays A, et al. Visual field defects and the risk of motor vehicle collisions among patients with glaucoma. Invest Ophthalmol Vis Sci. 2005; 46:4437-4441.

[7]. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977; 159-174.

[8]. Keltner JL, Johnson CA, Cello KE, et al. Classification of visual field abnormalities in the ocular hypertension treatment study. Arch Ophthalmol. 2003; 121:643-650.

[9]. Stewart, J. Calculus Concepts and Contexts, 2nd ed. Brooks/Cole. Pacific Grove, CA. 2001.

[10]. Sample PA, Girkin CA, Zangwill LM, et al. The African Descent and Glaucoma Evaluation Study (ADAGES): design and baseline data. Arch Ophthalmol. 2009; 127:1136-1145.

[11]. Racette L, Liebmann JM, Girkin CA, et al. African Descent and Glaucoma Evaluation Study (ADAGES): III. Ancestry differences in visual function in healthy eyes. Arch Ophthalmol. 2010; 128:551.

[12]. Lawrence I, Lin K. A concordance correlation coefficient to evaluate reproducibility. Biometrics. 1989; 255-268.

[13]. Steichen TJ, Cox NJ. A note on the concordance correlation coefficient. The Stata Journal. 2002; 2:183-189.

[14]. Cox NJ.Speaking Stata: Graphing agreement and disagreement. Stata Journal. 2004; 4:329-349.