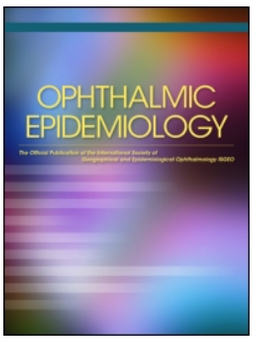

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ORIGINAL ARTICLE

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# The National Eye Survey of Trinidad and Tobago (NESTT): Rationale, Objectives and Methodology

Tasanee Braithwaite[a], Neville Q. Verlander[b], Debra Bartholomew[c], Petra Bridgemohan[d], Kevin McNally[e], Allana Roach[f], Subash Sharma[f], Deo Singh[g], Konrad Pesudovs[h], Surujpal Teelucksingh[f], Christine Carrington[f], Samuel Ramsewak[f], and Rupert Bourne[a], on behalf of the NESTT Study Group

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**ABSTRACT**

***Purpose***: This paper describes the rationale, study design and procedures of the National Eye Survey of Trinidad and Tobago (NESTT). The main objective of this survey is to obtain prevalence estimates of vision impairment and blindness for planning and policy development.

***Methods***: A population-based, cross-sectional survey was undertaken using random multistage cluster sampling, with probability-proportionate-to-size methods. Eligible participants aged 5 years and older were sampled from the non-institutional population in each of 120 cluster segments. Presenting distance and near visual acuity were screened in their communities. People aged 40 years and older, and selected younger people, were invited for comprehensive clinic assessment. The interview included information on potential risk factors for vision loss, associated costs and quality of life. The examination included measurement of anthropometrics, blood glucose, refraction, ocular biometry, corneal hysteresis, and detailed assessment of the anterior and posterior segments, with photography and optical coherence tomography imaging. Adult participants were invited to donate saliva samples for DNA extraction and storage.

***Results***: The fieldwork was conducted over 13 months in 2013–2014. A representative sample of 10,651 individuals in 3410 households within 120 cluster segments identified 9913 people who were eligible for recruitment.

***Conclusion***: The study methodology was robust and adequate to provide the first population-based estimates of the prevalence and causes of visual impairment and blindness in Trinidad and Tobago. Information was also gathered on risk factors, costs and quality of life associated with vision loss, and on normal ocular parameters for the population aged 40 years and older.

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## Introduction

The Global Burden of Disease (GBD) Study estimated that, in 2010, 32.4 million people worldwide were blind and 191 million were moderately or severely visually impaired.[1] Around 80% of vision loss is avoidable, through cost-effective interventions to prevent, screen and treat sight-threatening eye disease.[2] Avoidable vision loss remains a key public health concern.[2] The GBD study also modeled vision loss prevalence by region and country, but highlighted the paucity of population-based data in the Caribbean region (Table 1).[3–12] In addition to knowing the prevalence of vision loss, epidemiological data on the risks, impacts and costs of vision loss on individuals and society are also important. Such country-specific data provides a robust foundation for the development of evidence-based policies and services which aim to reduce avoidable blindness and to support people with vision loss to achieve their full potential.[2]

There was no previous population-based data on vision loss in Trinidad and Tobago, a high-income, twin island republic in the Caribbean with a population of 1.3 million[13] and a total landmass of 5128 km$^2$. Expenditure on health-care accounts for 4.8% of gross domestic product and eye care services are available from both the private and public health sector.[14] Several factors suggested that the population was at particular risk of sight-threatening eye disease. First, the demographic profile is that of an aging population,[13] and with age the frequencies of cataract, glaucoma and other age-related eye diseases increase.[15] Second, the population has a unique and heterogeneous ethnic mix,[13] which may put it at increased genetic risk of certain eye diseases.[16–18] Furthermore, there is an emerging epidemic of chronic non-communicable diseases, which

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**Table 1.** Previous population-based surveys of vision impairment in the Caribbean.

| Location | Population | Year | Age, years | Sample size, *n* (response rate, %) | Prevalence outcomes |
|---|---|---|---|---|---|
| Barbados | National | 1987 | 40–84 | 4631 (82.1) | Visual impairment,[4] blindness, glaucoma,[5] cataract,[6] DR,[7] AMD,[9] refractive error[8] |
| Cuba | Local (urban) | 2005 | 50–99 | 2716 (98.4) | Blindness, low vision[10] |
| Dominican Republic | National | 2008 | 50–99 | 3873 | Blindness, low vision[11] |

DR, diabetic retinopathy; AMD, age-related macular degeneration.

are associated with ocular complications. An estimated 56% of the adult population is overweight or obese, 26–30% are hypertensive, and 19–21% have diabetes mellitus.[19,20] Recognizing the value of country-specific data to inform a national eye care strategy, the Ministry of Health of the Government of Trinidad and Tobago approved funding for a National Eye Survey in 2012. This paper outlines the rationale, study design and procedures of the National Eye Survey of Trinidad and Tobago (NESTT).

## Materials and methods

### Study design

The NESTT was a population-based, cross-sectional survey of the population aged 5 years and older. The study was conducted through a collaboration between Anglia Ruskin University (United Kingdom), and the University of the West Indies (Trinidad and Tobago). An ancillary genetic epidemiology study was conducted in collaboration with Duke University (United States of America).

### Aims

#### Primary objective

To estimate the prevalence of presenting blindness and vision impairment among adults aged 40 years and older.

#### Secondary objectives in persons aged 40 years and older

(1) To determine the principal cause and risk factors associated with blindness and moderate or severe vision impairment (MSVI); (2) To estimate the prevalence of common eye conditions; (3) To establish a normative database of various biometric and ocular parameters; (4) To explore the cost and impact of vision impairment on quality of life; (5) To investigate the availability of low vision rehabilitation services and barriers to uptake; (6) To investigate the effectiveness of eye care services, including cataract surgical coverage and cataract surgical rate; (7) To establish a bio repository of saliva DNA samples to enable future genome-wide association studies of ocular and cardiovascular disease.

In addition, we aim to estimate the prevalence and causes of presenting blindness and MSVI in people aged 5–39 years.

### Participants

The total population of Trinidad and Tobago was 1,328,019 in 2011, and the non-institutionalized population was 1,322,546.[13] An eligible person was defined as someone resident in Trinidad or Tobago for more than 6 months, who was aged 5 years or older at their last birthday, and who was a usual resident of the selected household. The last was defined as sleeping in the household most nights of the week and sharing at least one daily meal with other household members.[13] People currently abroad or in an institution (e.g. hospital, prison) and not anticipated to return within one month were excluded.

### Sample size

The study population required to address the primary objective comprised individuals aged 40 years and older. The Barbados Eye Survey suggested an expected prevalence (p) of best-corrected blindness of 1.7%.[4] The sample size was chosen to achieve a desired level of absolute precision (d) of 0.5% in the width of the 95% confidence interval, and a design effect (DEFF) of 1.4;

$$n = \frac{1.96^2\, p(1-p)(DEFF)}{d^2}$$

The sample was adjusted for a potential non-response of 20%, based on the Barbados Eye Survey,[5] to generate a target sample of 4147. A total of 35 persons aged 40 years and older were sampled in each of 120 enumeration districts (EDs) to achieve this target ($n$ = 4200). This sample size was anticipated to give the study adequate power to estimate the prevalence of major eye conditions affecting older persons (Table 2). The population aged 5 years and older comprise 92.91% of the total population.[13] Within this, 57.83% are aged 5 to 39 years and 42.17% are aged 40 years and older. We therefore expected to find 5760 eligible people aged 5 to 39 years living alongside those aged 40 years and older, giving a total anticipated sample of 9886 people.

**Table 2.** Sample size required to give precise estimates of the prevalence of different ocular diseases, in the National Eye Survey of Trinidad and Tobago (NESTT).

| Condition | Prevalence, % | Precision, 95% CI | Required sample, *n* |
|---|---|---|---|
| Blindness | 1.70[4] | 1.19–2.21 | 3455 |
| Vision impairment | 5.90[4] | 4.90–6.90 | 2986 |
| Myopia | 21.9[8] | 19.9–23.9 | 2300 |
| Hyperopia | 46.9[8] | 44.4–49.4 | 2143 |
| Cataract | 41.0[6] | 38.5–43.5 | 2082 |
| Glaucoma | 7.0[5] | 5.8–8.2 | 2431 |
| Diabetic retinopathy | 1.0[7] | 0.5–1.5 | 2130 |
| Exudative AMD | 0.50[9] | 0.25 – 0.75 | 4281 |

Based on a 2-sided type 1 error, α, of 0.05 for different prevalence rates, and adjusted for the design effect due to clustering (1.4), but not including anticipated non-response (for which the sample was increased by 20%).
CI, confidence interval; AMD, age-related macular degeneration.

## Sampling frame

The visitation record from the 2011 Population and Household Census was used as the sampling frame. This was stratified into the two islands containing five regions (one in Tobago, four in Trinidad), 21 municipalities, and 2827 mutually exclusive EDs. An ED was defined as a geographical area comprising approximately 150 to 200 households.[13] For each ED, the population size, sex distribution, age distribution, and number of buildings and households were known.

## Sampling strategy: Multi-stage randomized cluster

### Primary sampling unit: The enumeration district

Random cluster sampling selected 120 EDs as the primary sampling units, by probability-proportional-to-size (PPS) methods.[21] PPS sampling was chosen to reduce bias in survey estimates, because the EDs differed in population size. The mean population size was 472 people (standard deviation, SD, 189) ranging from 1 to 1655 people. Each person in the population had an equal probability of being selected. The distribution of the 120 clusters is shown in Figure 1, and reflects the geospatial population density.

### Secondary sampling unit: Compact segment of households

A detailed field map of each ED was obtained from the Central Statistics Office (CSO). Consecutive buildings were numbered, and the ED was divided into a number of segments determined by the population size of the ED, with each segment containing approximately 100 people. One segment was selected at random using Microsoft Excel, by an investigator not directly involved in enumeration. The segment's buildings were marked clearly on the map and given to the enumerator, who was instructed to proceed from the first marked building to consecutively numbered buildings.

### Tertiary sampling unit: Eligible individuals

The enumerator attempted to contact everyone aged 5 years and older living in selected households to ascertain eligibility. If residents were not home on the first visit, a leaflet detailing the study was left, including a contact telephone number for the lead survey ophthalmologist. Enumeration continued until 35 people aged

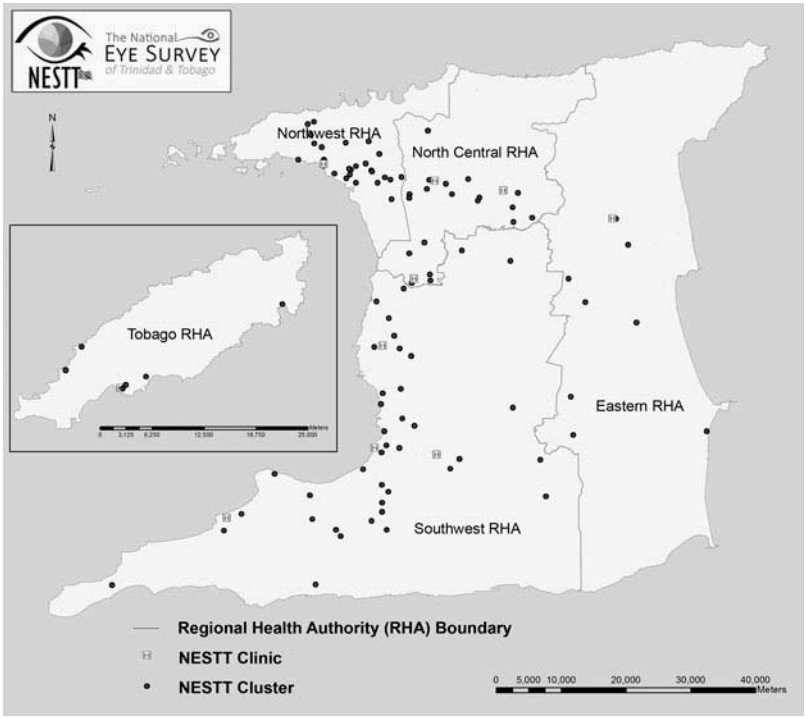


**Figure 1.** Map of Trinidad and Tobago showing distribution of the 120 National Eye Survey of Trinidad and Tobago (NESTT) clusters.

40 years and older in consecutive households were enumerated. If residents were not at home or refused, information on eligibility was sought from neighbors or relatives. Sampling was with non-replacement. The sample therefore included eligible people who could not be contacted, despite at least three attempts by both enumeration and screening teams, and those who refused participation. This strategy was chosen to minimize bias.

### Recruitment strategy

Recruitment of participants followed a detailed strategy that was devised following a series of pilot studies. Eligible people who agreed to participate were given a full verbal and written description of the study. Both enumeration and screening teams visited each cluster on multiple occasions, at differing times and on different days, including weekends. If eligible for clinic, a written appointment date and time were given and participants were telephoned or sent an SMS message with a reminder the preceding day. Non-attenders were re-contacted by telephone up to three times to offer another appointment. Telephone scripts were developed to ensure consistent delivery of key information. People who refused enumeration were contacted by the clinical team in a further attempt to recruit them, and if still not interested were documented as "refused." In addition to an individualized communication strategy, various additional measures were taken to increase participation. These included information releases on national television, in the newspaper, on the radio, on websites and via social media (Facebook), sensitization of eye and primary care professionals to the study, and engagement with community leaders where these could be identified. A separate Community Engagement and Sensitization Strategy sensitized the general public and participants to the ancillary NESTT genetics study.[22]

### Staff, training and logistics

The enumeration team included a Field Supervisor, and 18 CSO-trained enumerators who had each completed at least one national census. The clinical team included two survey ophthalmologists, three optometrists, two nurses, two enrolled nursing assistants, and two data entry staff. The clinic was offered 5 days a week from 7 am to 3 pm, including Saturdays. Pairs of the clinical team led community vision screening, during afternoons and weekends, with assistance from six part-time vision screeners. The genetic study sample team included three research assistants under the supervision of a human geneticist. The project was managed by the lead survey ophthalmologist, and by a part-time administrator, with oversight from the Principal Investigator and co-investigators.

Staff underwent training by the Principal Investigator, lead survey ophthalmologist, human geneticist, field supervisor and a low vision specialist. The CSO-trained enumerators were given detailed enumeration manuals, and underwent one day of NESTT-specific training followed by supervised fieldwork in all clusters. The clinical and screening teams had dedicated training for one month. Technicians from Topcon (Topcon Corporation, Tokyo, Japan) and Medilex (Medilex LLC, Doral, FL, USA) trained the team in the operation of the ophthalmic equipment. A detailed manual of operations and standard operating procedures were given to team members.

The NESTT survey clinic was situated in 11 locations sequentially, within all five regions. Three locations were in Regional Health Authority (RHA) facilities, one was within the University, and seven were on a specially equipped NESTT mobile unit parked at RHA facilities. The distance between the 120 clusters and the clinic ranged from 50 m to 43 km, but was generally within 10 km. Poor road quality in some rural areas, and the sensitivity of the ophthalmic equipment, precluded the mobile unit from visiting additional locations.

### Survey pathway

#### Enumeration, consent and vision screening

The enumerators explained the purpose of the study, ascertained eligibility, and obtained verbal consent to participate. They collected individual contact information and core demographic and socioeconomic data from eligible household members, and completed a questionnaire on each household (Table 3). Written informed consent to participate in the survey was obtained by the vision screening team. Children aged 5–12 years and young people aged 13–17 years were asked to sign separate assent forms, and consent was obtained from a legal guardian. Eligible persons with a disability potentially affecting understanding were identified at enumeration and flagged to the survey ophthalmologist, who arranged to speak with the family or visit the home to undertake a mental capacity assessment. If they were considered to lack capacity to give informed consent on account of a persistent impairment in the functioning of the brain, the reason for this was documented. They were counted as a non-responder and were not recruited to participate in the study. They were offered an eye examination by the ophthalmologist if this was felt to serve their best interests.

**Table 3.** Variables included in structured questionnaires, National Eye Survey of Trinidad and Tobago (NESTT).

| Questionnaire | Variables | Source of questions |
|---|---|---|
| Individual enumeration | Sex, age, date and place of birth, ethnicity, position in household, employment status, number of years resident in Trinidad and Tobago, basic medical and ophthalmic history, self-reported vision status, disabilities, and reason if not able to attend clinic for full assessment | Trinidad and Tobago Population and Housing Census,[13] RAAB instruction manual[27] |
| Household enumeration | Wall and roof material, main fuel used for cooking, household ownership status, and ownership of a set of preselected goods | Trinidad and Tobago Population and Housing Census[13] |
| Demographic | Place of birth, marital status, main language, religion, education, employment, household income, driving history, communication access, and health insurance status | Trinidad and Tobago Population and Housing Census,[13] International Standard Classification of Occupations[28] |
| Socioeconomic | Usage and out-of-pocket expenditure on health care over past 12 months, usual transportation mode, informal care required on account of vision loss, number of eye care-related sick days, and lost income in the past 12 months | UKPDS Study Healthcare Costs[29] |
| Medical and ophthalmic | Past medical and ocular history, medication history and compliance, family history, and exposure history (alcohol, tobacco, and illicit drugs) | The INTERHEART study,[30] RAAB instruction manual[27] |
| Patient-reported outcomes | Three standardized instruments: VisQoL, the IVI and the 5-level EuroQol questionnaires. These instruments were tested and validated in the pilot survey. The IVI was only administered to those with best-corrected vision worse than 6/18 in the better seeing eye, and to a randomly selected control group of people with normal vision | VisQoL instrument,[31] IVI,[32,33] EuroQol[34,35] questionnaires |
| Low vision | Age at onset, duration and rate of vision loss, eye care service use history, functional adaptations and use of low vision aids, access to low vision services and barriers, feedback on experience using eye care services, and potential to improve quality of life of visually impaired people | Developed through consultation with the Blind Welfare Association, Trinidad and Tobago |
| Cardiovascular | History of passive smoke exposure, activity level at work and during leisure time, dietary intake of fruit and vegetables, sleep and snoring history | The INTERHEART study[30] |

RAAB, rapid assessment of avoidable blindness; UKPDS, United Kingdom Prospective Diabetes Study; VisQoL, Vision Quality of Life Index; IVI, Impact of Visual Impairment.

Monocular presenting distance visual acuity was measured at eye level at 3.0 m, and binocular presenting near visual acuity was measured at 40.0 cm, using logarithm of the minimum angle of resolution (LogMAR) letter optotype charts (Precision Vision, La Salle, IL, USA; Table 4). If the participant was not fully literate, PV Number charts, with matching cards if needed, were offered (Precision Vision). The participant was tested with their habitual optical correction (spectacles or contact lenses), if applicable.[23] Vision screening was conducted in an outside but shaded location to achieve supra-threshold chart illumination of at least 160 cd/m$^2$, without incident glare.[23] The Early Treatment Diabetic Retinopathy Study (ETDRS) fast protocol was used for measurement of distance visual acuity on the Sloan 3 metre 2000 Series Revised ETDRS Chart, Precision Vision, La Salle, IL, USA; Table 4).[24,25] The standard ETDRS protocol was used for measurement with the PV numbers chart, and for measurement of near visual acuity.[26] The visual acuity score was specified in terms of the number of optotypes correctly identified, and converted back to the LogMAR scale later for analysis. If the participant was unable to correctly identify the optotypes at 3.0 m they moved to 1.50 m and 0.75 m sequentially. If no optotypes could be identified at 0.75 m, visual acuity was documented as "counting fingers," "hand movements," "perception of light" or "no perception of light."

## Survey clinic

All eligible people aged 40 years and older were invited to attend the regional NESTT survey clinic for free comprehensive assessment. People aged 5 to 39 years were invited if their presenting vision was worse than 6/12 or if they had diabetes or glaucoma. On arrival, each participant was assigned a unique survey identification number. The clinic pathway is summarized in Figure 2.

## Questionnaires

The Epi Info software package (version 3.5.4, Centers for Disease Control and Prevention, Atlanta, GA, USA) was used to prospectively administer a series of structured questionnaires. The questionnaires were developed from question sets used in previous studies, and included demographic,[13,27,28] socioeconomic,[13,29] medical and ophthalmic history variables.[27,30] Three validated patient-reported outcome measure instruments were also included.[31–35] A supplementary questionnaire on low vision was developed following focus group feedback with clients registered with the Blind Welfare Association in Trinidad and Tobago. This was administered to those with a best-corrected visual acuity in the better-seeing eye worse than 6/18. A supplementary questionnaire on cardiovascular risk factors was administered to those who

**Table 4.** Variables included in the examination, with brief outline of equipment and measurement protocol, National Eye Survey of Trinidad and Tobago (NESTT).

| Examination variable | Equipment | Measurement protocol |
|---|---|---|
| *Vision screening* | | |
| Distance visual acuity | 3 m 2000 Series Revised ETDRS Chart, or PV Numbers acuity vision test, Precision Vision, La Salle, IL, USA | If literate: ETDRS Fast Protocol;[24,25] Beginning with the top row the screener invited the participant to identify only one letter per line by briefly pointing. To guarantee the same degree of difficulty for each row, only Sloan letters of intermediate difficulty coefficient were chosen (D, K, V, R, H). At the first letter read incorrectly the subject was required to read the whole preceding row. This step was repeated upward if the subject made two or more errors. The participant then read all rows downward, letter by letter, until the screener determined that no further meaningful readings could be made despite urging the subject to read or guess.<br>If not literate: Standard ETDRS Protocol:[26] participants asked to identify all PV numbers from the top, using a matching card if needed, with the same stopping rules as the ETDRS-Fast protocol |
| Near visual acuity | Sloan 2-sided ETDRS Format Near Point Test or PV Numbers Near Vision Card, both with 40 cm measuring cord, Precision Vision,; Reading lamp | Standard ETDRS Protocol:[26] participants asked to read all letters from the top, with the same stopping rules as the ETDRS-Fast protocol |
| *Medical exam* | | |
| Weight | Analogue weighing scale | Nurse measured to nearest kilogram with shoes removed |
| Height | Wall-mounted tape measure with horizontal measuring level | Nurse measured after removal of shoes to nearest centimeter with participant standing against wall, and stretching their back with their head level and feet together |
| Waist circumference | Non-stretch fiberglass tape measure | Nurse measured at the smallest circumference between the ribs and iliac crest, to the nearest 1 cm, while standing with the abdomen relaxed at the end of a normal expiration. Where there was no natural waistline, measurement was taken at the level of the umbilicus |
| Blood pressure and pulse rate | HEM 907XL IntelliSense Professional Digital Blood Pressure Monitor, Omron Corporation, Kyoto, Japan | Nurse measured blood pressure and pulse rate with participant seated after 5 minutes of rest, using an appropriate cuff size for the left arm circumference |
| Capillary blood glucose | Accu Check, Roche, Basel, Switzerland | Nurse swabbed finger with alcohol wipe and used safety lancet used to obtain drop of blood. Glucose level recorded (mg/dL). Fasting defined as having had no food and no drink except water for 8 hours. If not fasted, recorded as random level. |
| *Optometry exam* | | |
| Auto refraction, keratometry and corneal topography | KR8000-PA, Topcon, Tokyo, Japan | Auto refraction sphere, cylinder and axis, and corneal radius of curvature in the horizontal and vertical meridian. One measurement taken of each eye, and repeated if measurement error |
| Spectacle prescription | Model 11360 Manual Lens meter, American Optical, Southbridge, MA, USA | Manual focimetry |
| Habitual reading distance | Tape measure | Participant asked to hold the near chart at their usual preferred reading distance and this "habitual distance" was measured from the corneal surface to the chart with a tape measure |
| Optimal near add | Trial Lens Frame, Viewlight, Miami, FL, USA; Trial Lens Set 266BL, Viewlight | Trial frame fitted to the participant's face with the distance prescription mounted (that required to achieve at least 6/9 with auto-refraction correction, or the lens achieving best correction). Bracketing used to identify the plus DS lens prescription, ranging from 0.25DS to 3.00DS, required to achieve best near visual acuity in each eye, with the other occluded. |
| Contrast sensitivity | Mars Letter Contrast Sensitivity Test, Precision Vision | Binocular presenting contrast sensitivity at 50 cm measured using the Mars chart, with participants in their habitual near optical state |
| *Ophthalmic exam* | | |
| Face, adnexa, ocular movements | | Face, adnexa, globe, ocular alignment and ocular movements documented normal or abnormal with description if abnormal |
| Pupils | Pen torch | Appearance of the pupils, direct, indirect and relative pupil reactions documented as normal or abnormal with description if abnormal |
| Anterior segment | Slit lamp model BQ-900, Haag-Streit, Bern, Switzerland | Any abnormalities of the anterior segment documented. Van Herick anterior chamber depth graded: 4 (≥100%), 3 (>25–50%), 2 (25%) or 1 (<25%)[36] |

(*Continued*)

**Table 4.** (Continued).

| Examination variable | Equipment | Measurement protocol |
|---|---|---|
| Posterior segment (after dilation) | 90D MaxField and 78D MaxField High Mag, Ocular Instruments, Bellevue, WA, USA; Slit lamp model BQ-900, Haag-Streit | Lens graded using the LOCS III grading system, with comparison to the standard photographic transparency.[37] Nuclear color and opalescence grades were amalgamated into a single grade.[38] Vitreous, macula, retina and optic disc[39] were documented as normal or abnormal, with description if abnormal |
| *Ocular imaging and measurement* | | |
| Intraocular pressure and corneal hysteresis | Ocular Response Analyzer, Reichert Technologies, New York, NY, USA | Three measurements taken of each eye, aiming to optimize the signal to noise ratio, and the best-waveform values for two measures of IOP (corneal compensated IOP and Goldmann-correlated IOP) documented for each eye |
| Ocular biometry | Lenstar LS 900$^{R}$, Haag-Streit | Corneal thickness, axial length, white-to-white distance, lens thickness, anterior chamber depth, keratometry and pupillometry. Three measurements taken of each eye |
| Color photographs and optical coherence tomography | 3DOCT2000, Topcon Corporation | B-scan of the temporal iridocorneal angle, radial B-scan of the cornea, and an external color photograph. After dilation, two 45° color photographs of ETDRS standard field 1 (centered on the optic disc) and ETDRS standard field 2 (centered on the fovea).[40] Spectral domain optical coherence tomography images including the "macula wide," "5-line cross" and "3D disc." |

ETDRS, Early Treatment Diabetic Retinopathy Study; DS, diopter sphere; LOCS, Lens Opacities Classification System; IOP, intraocular pressure.

donated a saliva sample for the genetics substudy.[30] The questionnaire variables are summarized in Table 3.

## Examination

The examination stations included a general medical examination, conducted by a nurse; an eye examination before and after dilation, including assessment of the anterior chamber depth,[36] lens status,[37,38] and optic disc,[39] conducted by an ophthalmologist; and an assessment of vision and refractive status, conducted by an optometrist. Additional stations included detailed ocular imaging and measurement, with fundus photography,[40] optical coherence tomography, ocular biometry, and measurement of corneal hysteresis. The examination variables, equipment and measurement protocols are outlined in Table 4. In addition, some participants underwent further examination based on predefined eligibility criteria. The additional variables obtained in a subset of participants are summarized in Table 5 and include glycosylated hemoglobin,[41] best-corrected distance acuity, gonioscopy,[39,42] automated visual field testing and low vision assessment. Examination findings were entered on a paper case report form (CRF) in addition to Epi Info. People aged 5 to 39 years who were eligible to attend the clinic had a slightly more limited examination (Figure 2).

After the first slit-lamp examination, tropicamide 1% (1 drop) and phenylephrine hydrochloride 2.5% (1 drop) were instilled into each eye. An additional drop of each was instilled after a 15-minute interval if inadequate mydriasis was apparent. All participants had their pupils dilated providing the iridocorneal angle was not occludable. A normal angle was defined as a van Herick limbal chamber depth ≥25%, or following gonioscopy as visibility of the posterior third of the trabecular meshwork for more than 270°.[39] Dilation was avoided in those with known allergy to mydriatic eye drops, those with potentially occludable angles, and those who declined dilation despite encouragement from the survey ophthalmologist.

## DNA saliva sample

The survey ophthalmologist outlined the genetics substudy and ascertained whether adult participants were willing to discuss participation further. If they were, the genetics research assistant delivered comprehensive information in a semi-structured format. Participants were free to decide not to donate a saliva sample for extraction and storage of DNA, to donate a sample for future genetics studies relating to ocular and cardiovascular disease only, or to donate a sample for both this and for addition to the Duke University Biobank in the USA. The decision was documented on the case report form. Written consent was obtained, and participants were asked to fill an Oragene tube (DNA Genotek, Ontario, Canada) with saliva, according to the manufacturer's instructions. A unique barcode supplied by the Duke University Biobank was placed on the Oragene saliva tube, on the case report form, and on the genetics consent form. Samples (maintained at room temperature) were shipped

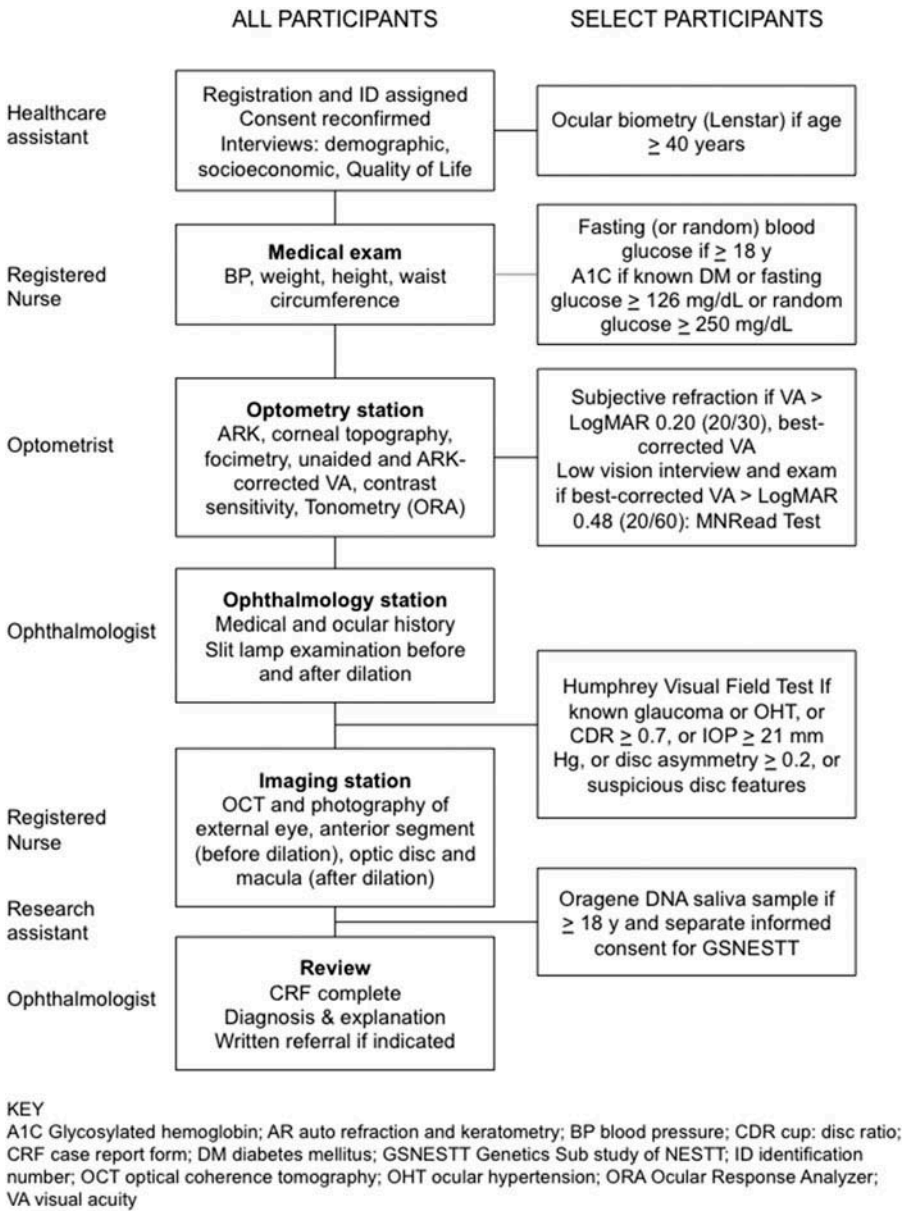


**Figure 2.** National Eye Survey of Trinidad and Tobago (NESTT) clinical pathway.

to Duke University for future DNA extraction, quantification and genetic analyses.

### *Domiciliary visits*

Eligible people who failed screening and were unable to attend the clinic owing to mobility issues, frailty, illness or care of dependents were offered a home visit by one of the survey ophthalmologists. A limited questionnaire was administered to obtain key data. Assessment to determine the principal cause of vision loss included pupil reactivity, pinhole distance visual acuity, and dilated examination using a direct ophthalmoscope (Professional Ophthalmoscope 3.5v, Keeler, Windsor, UK).

### *Service component*

At the conclusion of the clinic visit participants were given a full explanation of any findings, and a written summary for onward referral if any abnormalities were identified. Participants chose public or private sector referral. Imaging results were emailed or transferred to external memory sticks on request. Topical eye drops were dispensed at no cost for those requiring urgent treatment.

### *Quality assurance*

The field supervisor coordinated the activities of the enumeration team. The lead survey ophthalmologist

**Table 5.** Examination procedures for a subset of participants according to specific indications, National Eye Survey of Trinidad and Tobago (NESTT).

| Examination variable | Equipment | Measurement protocol | Indication |
|---|---|---|---|
| Glycosylated hemoglobin A1C | Rapid point-of-care assay machine (DCA Vantage Analyzer, Siemens, Berlin, Germany) | Droplet of capillary blood obtained with safety lancet. Rapid point-of-care assay performed according to manufacturer's instructions | Previous diagnosis of diabetes or a fasting blood glucose ≥126 mg/dl (7.0 mmol/l) or a random blood glucose >200 mg/dL (11.1 mmol/L)[41] |
| Best-corrected visual acuity | Trial Lens Frame, Viewlight, Miami, FL, USA; Trial Lens Set 266BL, Viewlight | Subjective refraction performed by optometrist | Presenting distance visual acuity worse than LogMar 0.20 (approximately 6/9) in either eye |
| IOP (manual) | AT900 Applanation Tonometer, Haag-Streit, Bern, Switzerland; proxymetacaine hydrochloride 0.5%; dry strip of fluorescein; Slit lamp model BQ-900, Haag-Streit | Care taken to use just enough fluorescein to obtain mires of standard thickness. IOP measured once in each eye using Goldmann applanation tonometer | Ocular Response Analyzer measurement of IOP not possible |
| Cup-to-disc ratio (manual) | 78D MaxField High Mag, Ocular Instruments, Bellevue, WA, USA; Slit lamp model BQ-900, Haag-Streit | Optic disc examined at x10 magnification and vertical dimensions of the disc and cup measured using the eyepiece light, in 0.1 mm units, excluding areas of peripapillary atrophy and Elschnig's ring. The margins of the cup were defined by stereoscopic examination as the point of maximum inflexion of contour, and the height of the cup was measured as the vertical distance between the points of maximal centrifugal extension of the cup between 11 and 1 o'clock and 5 and 7 o'clock.[42] For small discs with no visible cup, the measurement was taken as the diameter of the emerging retinal vessels[39] | Automated cup-to-disc ratio measurement not possible owing to OCT machine malfunction or the presence of significant media opacity |
| Gonioscopy | Magna View Gonio Lens without flange, Ocular Instruments; proxymetacaine 0.5%; Gel tears, Bausch & Lomb Incorporated, Rochester, NY, USA | The visibility of the four key structures was documented | Van Herick limbal chamber depth grade 2 or less[36] |
| Visual field test | Humphrey Visual Field Analyzer II (model 740i), Carl Zeiss, Meditec AG, Jena, Germany | 24-2 SITA static, threshold-related visual field test performed with near refractive correction in place, prior to dilation, in both eyes. Test reliability determined by the instrument's algorithm. Test repeated once if Glaucoma Hemifield Test abnormal, borderline, or reduced sensitivity | (1) Vertical cup-to-disc ratio ≥0.70<br>(2) IOP ≥21mmHg<br>(3) Abnormal optic disc features suggestive of glaucoma<br>(4) History of diagnosed glaucoma or ocular hypertension<br>Not performed in eyes with a visual acuity worse than 0.48 Log MAR (6/18) |
| Low vision tests | Mars Letter Contrast Sensitivity Test, Precision Vision, La Salle, IL, USA; MN Read English Continuous text chart Black/White, Precision Vision | (1) Uniocular Mars contrast sensitivity in best-corrected state<br>(2) Uniocular MN Read test in best-corrected state | Distance best-corrected visual acuity in the better seeing eye worse than 6/18 (Log MAR 0.48) |

IOP, intraocular pressure; OCT, optical coherence tomography; SITA, Swedish Interactive Threshold Algorithm; LogMAR, logarithm of the minimum angle of resolution.

coordinated the activities of the clinical and screening teams and audited enumeration in every cluster. If the number of "no contact" households was >3, or if the initial refusal rate was high, the lead survey ophthalmologist visited the cluster to review the enumeration and recruitment. Where additional enumeration of individuals who were skipped in error resulted in more than 35 people aged 40 years and older being included for a given cluster, this was accounted for in the statistical analysis. Supervisory visits were made to the survey clinic by co-investigators to monitor practices and ensure protocols were being followed. Following the training period, inter-observer agreement in key examination variables was analyzed using standard statistical software (Stata release 13.1; StataCorp LP, College Station, TX, USA). For the first 6 months of fieldwork each pair of vision screeners included either a supervising ophthalmologist or optometrist to provide ongoing training and quality assurance in the measurement of visual acuity. The Moorfields Eye Hospital Reading Centre, London, UK, graded retinal photographs and optical coherence tomography scans to provide independent validation of the findings.

## Data management

Clinic data were identifiable by survey ID number only. In-built consistency checks in Epi Info, and validation through duplicate entry of key variables, was used to correct errors in data entry. The exported databases were copied to an external hard drive daily, and the data from the ophthalmic equipment were exported weekly. A designated team member was responsible

for the secure storage of the external hard drive at all times. The completed CRF and databases were cross-checked monthly to check for and correct any data entry errors. Forms were transported to a central medical records office at the University of the West Indies with restricted access for secure storage.

### Security considerations and deviation from the protocol

Trinidad and Tobago's homicide rate was 37.9 per 100,000 in 2012.[43] Criminal activity was particularly concentrated in certain areas east of the capital, Port of Spain, and escalated unpredictably. It was anticipated that some randomly selected EDs might be too dangerous to enumerate, even for experienced enumerators native to those districts. In this event, we planned to replace the ED with that closest in population size within the same municipality. In the case of EDs being too dangerous for door-to-door vision screening, screening was offered in safer locations (schools, churches, community centers) within a few 100 meters of the selected households.

### Statistical methods

Statistical analyses will be performed using standard statistical software (StataStata release 13.1). We will explore the raw data, and the characteristics of responders and non-responders, with simple descriptive statistics. The health-related utility values (from the EuroQol 5-dimension questionnaire, EQ5D) and vision-related utility values (from the Vision Quality of Life index, VisQoL) will be calculated from transformation of raw scores. Crude estimates for key outcome measures, including the prevalence of visual impairment and common diseases, the proportion incurring eye care costs, and the proportion suffering decrements in utility, will be adjusted to account for the multilevel survey design (by island and cluster), and weighted for the response rate in each cluster. A post-stratification adjustment will be made using the 2011 Population and Household Census for the non-institutional population of Trinidad and Tobago (stratified by 15 municipalities, 5-year age categories and sex). Multilevel regression analysis, taking into account the cluster (primary sampling unit), building and household number (secondary sampling unit), and individual (tertiary sampling unit), will be performed for single potential explanatory variables, which will be considered one at a time. Multilevel multiple regression models will be estimated to control for the effects of potential explanatory and confounding variables on the outcomes of interest. Analyses will be done for the ≥40 years and 5–39 years age groups separately. Logistic regression will be used for binary outcomes including responder, vision impaired, blind and for eye disease groups. Ordinal logistic regression will be used for expenditure on eye care, and utility value. For parameter estimation by single and multiple regression analysis, global $p$-values will be obtained using the likelihood ratio test, except when this is not possible, when the Wald $p$-value will be used. A $p$-value ≤0.05 will be taken to be statistically significant.

### Ethical and government approval

The study adhered to the tenets of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committees of the University of the West Indies (May 2012), the Ministry of Health of Trinidad and Tobago (May 2013) and Anglia Ruskin University (July 2013). Approval for an ancillary genetic epidemiology study was obtained from the Ethics Committees of the University of the West Indies (May 2012), Anglia Ruskin University (July 2013) and the Ministry of Health of Trinidad and Tobago (July 2014). DNA samples were stored in the genetic repository at the Centre for genetics at Duke University Medical Center, with approval from the Duke University Institutional Review Board.

## Results

The epidemiological survey commenced in October 2013 and concluded in November 2014. Sample collection for the genetics substudy commenced in August 2014 and concluded in June 2015. Overall, 119 of 120 randomly selected clusters (primary sampling units) were sampled as planned. One cluster in Port of Spain had to be excluded and replaced, according to the methodology outlined in the protocol, on account of unacceptably high security risk. Three clusters were categorized "very high risk" and 10 "high risk." Enumeration and vision screening in these communities was undertaken in safe locations and in some cases out of sequence, at times when criminal activity was lower. In total, a representative sample of 3410 households of 10,651 individuals were contacted, of whom 9913 people aged 5 years and older were eligible for recruitment (Figure 3). Figure 4 shows the geographical distribution of eligible persons, in comparison to the 2011 census population.

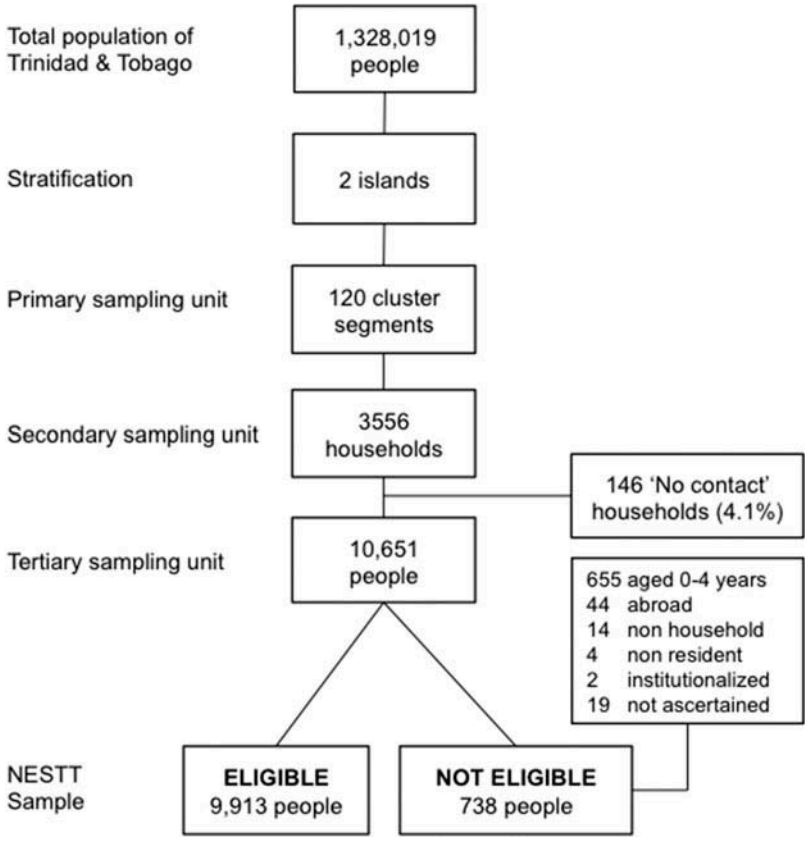


**Figure 3.** Multilevel selection of a nationally representative population-based sample for the National Eye Survey of Trinidad and Tobago (NESTT).

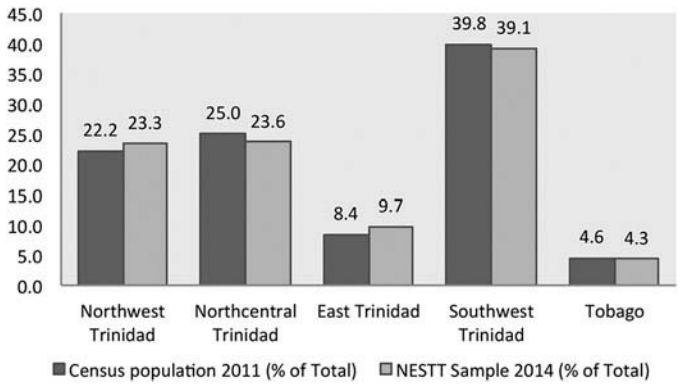


**Figure 4.** Geographic distribution of National Eye Survey of Trinidad and Tobago (NESTT) sample in comparison to the 2011 Population and Household Census population.

### *Inter-observer agreement for key examination variables*

During training, there was good agreement between observers for binary and categorical variables, including vision category, lens grade and ocular abnormalities, which were analyzed using a kappa coefficient (range 0.70–1.00; Table 6).[44–46] There was also acceptable agreement in the continuous variables visual acuity and intraocular pressure, which were analyzed using Bland-Altman limits of agreement (Table 7).[47–49]

## Discussion

The NESTT study design has a number of strengths. First, the rigorous sampling methodology ensured selection of a representative sample of the target

**Table 6.** Kappa coefficient for inter-observer agreement in binary and categorical examination variables, National Eye Survey of Trinidad and Tobago (NESTT).

| Observers | Examination variable | Kappa (*p*-value) |
|---|---|---|
| All vision screeners | Monocular distance visual acuity | 0.81 (<0.0001) |
| | Visual acuity ≥6/6 | 0.76 (<0.0001) |
| | Visual acuity <6/6 and ≥6/18 | 0.85 (<0.0001) |
| | Visual acuity <6/18 | |
| Two survey ophthalmologists | Lens opacity LOCS III[a] | 0.70 (<0.0001)[a] |
| | Nuclear | 0.75 (<0.0001)[a] |
| | Cortical | 0.86 (<0.0001)[a] |
| | Posterior subcapsular | |
| Two survey ophthalmologists | Van Herick limbal chamber depth | 0.79 (<0.0002) |
| Two survey ophthalmologists | Pupil normal or abnormal | 1.00 (<0.0001) |
| Two survey ophthalmologists | Macula normal or abnormal | 1.00 (<0.0001) |
| Two survey ophthalmologists | Retina normal or abnormal | 1.00 (<0.0001) |
| Two survey ophthalmologists | Optic disc normal or abnormal | 0.87 (<0.0001) |

[a]Kappa weighting: 1, 0.6, 0.3, 0, 0, 0, 0.
20 eyes of 20 volunteers included in analysis.
LOCS, Lens Opacities Classification System.

national population. The design effect was reduced by inclusion of 120 clusters of 35 people aged 40 years and older. Careful oversight of enumeration minimized the risk of selection bias. Second, the comprehensive examination procedures will enable estimation of the prevalence of common, asymptomatic eye diseases and refractive errors in people aged 40 years and older. Third, the specialized ophthalmic equipment generated data on several novel variables, whose significance in relation to other variables and outcomes will be explored. The NESTT data will provide the first normative database of ocular biometric parameters for a Caribbean population. Fourth, like numerous other recent epidemiological surveys of eye disease,[50–52] the NESTT included DNA sampling. Next generation sequencing techniques will be used for genome-wide association studies to explore novel genetic risk factors for some of the common, complex, chronic ocular and cardiovascular diseases, whose etiology remains elusive. Last, the study design and reporting of the NESTT cross-sectional survey adhere to the recommendations outlined in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[53]

There were several limiting factors in the study design. First, resource constraints precluded the examination of a sufficiently large sample of 5–39-year-olds to give statistical precision around estimates in this age group. Second, the January 2011 Population and Housing Census was the latest available sampling frame, and was 29 months out of date at the time of cluster selection. Deaths, births, migration in and out of the country and between areas may have occurred during that interval, leading to population size change within different EDs. Probability proportionate to estimated size methods would have been preferred. However, this approach requires a full remapping of all households per ED, which was beyond the project's resources, and has seldom been achieved in previous epidemiological surveys of eye disease. Last, for logistical reasons visual fields were not tested on all participants but on the subsample of suspected glaucoma cases, and therefore field loss will not be included in our definition of blindness.

The prevalence, causes, risk factors and impact of visual impairment and blindness in the population of Trinidad and Tobago were unknown. Regional data were sparse,[3] applicable only to persons aged 40 years and older, and of questionable relevance to this population,[4] which has a heterogeneous ethnic composition.[13] The NESTT will provide novel, robust, population-based data to inform the

**Table 7.** Bland-Altman limits of agreement in the measurement of continuous examination variables, National Eye Survey of Trinidad and Tobago (NESTT).

| Variable (unit) | Observer | *N* | Mean (SD) and difference in mean (SD) | Bland-Altman upper and lower limits of agreement (95% CI) |
|---|---|---|---|---|
| Distance visual acuity (number of letters correctly identified) | Trainer (ophthalmologist) *versus* Each vision screener | 20 left eyes | Trainer: 56.4 letters (9.0), range 33–66<br>Most dissimilar screener: 55.4 letters (9.5), range 32–66<br>Mean difference: 1.1 letters (3.1), range −6–9 | Upper limit: 7 letters (95% CI 5, 10)<br>Lower limit: −5 letters (95% CI −3, −8)<br>100% within 10 letters (2 lines) of the trainer's measure; 85% within 5 letters (1 line) |
| IOP (mmHg) | Manual GAT *versus* Automated Goldmann-correlated IOP measured by the Ocular Response Analyzer (g-IOP) | 101 left eyes | GAT: 15.8 mmHg (4.1 mmHg), range 9–36 mmHg<br>g-IOP: 16.0 mmHg (4.8 mmHg), range 7–39 mmHg<br>Mean difference: 0.26 mmHg (2.2 mmHg) ($p$ = 0.25) | Upper limit: 4.2 mmHg (95% CI 3.4, 4.9 mmHg)<br>Lower limit: −4.7 mm Hg (95% CI −5.4, −3.9 mmHg)<br>83.2% of GAT IOP within 2 mmHg of g-IOP |

SD, standard deviation; CI, confidence interval; IOP, intraocular pressure; GAT, Goldman applanation tonometry.

rational development of a national eye care strategy that aims to address the unmet needs of the population and reduce the burden of avoidable vision loss.

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## Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the writing and content of this article.

The work included in this article forms part of Dr. Tasanee Braithwaite's thesis for the degree of Doctor of Medicine at the University of Oxford.

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