Prevalence and Causes of Blindness and Visual Impairment and Their Associated Risk Factors, in Three Tribal Areas of Andhra Pradesh, India

Citation
Singh, Nakul, Shiva Shankar Eeda, Bala Krishna Gudapati, Srinivasa Reddy, Pushkar Kanade, Ghanshyam Palamaner Subash Shantha, Padmaja Kumari Rani, Subhabrata Chakrabarti, and Rohit C Khanna. 2014. “Prevalence and Causes of Blindness and Visual Impairment and Their Associated Risk Factors, in Three Tribal Areas of Andhra Pradesh, India.” PLoS ONE 9 (7): e100644. doi:10.1371/journal.pone.0100644. http://dx.doi.org/10.1371/journal.pone.0100644.

Published Version
doi:10.1371/journal.pone.0100644

Permanent link
http://nrs.harvard.edu/urn-3:HUL.InstRepos:12717418

Terms of Use
This article was downloaded from Harvard University’s DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA

Share Your Story
The Harvard community has made this article openly available. Please share how this access benefits you. Submit a story.

Accessibility
**Prevalence and Causes of Blindness and Visual Impairment and Their Associated Risk Factors, in Three Tribal Areas of Andhra Pradesh, India**

Nakul Singh¹, Shiva Shankar Eeda²,³, Bala Krishna Gudapati²,³, Sri-nivasa Reddy²,³, Pushkar Kanade⁴, Ghanshyam Palamaner Subash Shantha⁵,⁶, Padmaja Kumari Rani⁷,⁸, Subhabrata Chakrabarti⁷, Rohit C Khanna⁷,⁸,

¹Biostatistics, Harvard School of Public Health, Boston, Massachusetts, United States of America, ²Andhra Pradesh Right to Sight Society, Hyderabad, India, ³School of Optometry and Vision Science, University of New South Wales, Sydney, Australia, ⁴Internal Medicine, St. Vincent Charity Medical Center, Cleveland, Ohio, United States of America, ⁵Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, United States of America, ⁶Department of Internal Medicine, Wright Center for Graduate Medical Education, Pennsylvania, United States of America, ⁷Brien Holden Research Centre, L.V. Prasad Eye Institute, Banjara Hills, Hyderabad, India, ⁸Allen Foster Research Centre for Community Eye Health, GPR International Centre for Advancement of Rural Eye care, L V Prasad Eye Institute, Hyderabad, India

**Abstract**

**Objective:** To assess the prevalence of blindness and visual impairment (VI), their associated causes and underlying risk factors in three tribal areas of Andhra Pradesh, India and compare this data in conjunction with data from other countries with low and middle income settings.

**Methods:** Using a validated Rapid Assessment of Avoidable Blindness methodology, a two stage sampling survey was performed in these areas involving probability proportionate to size sampling and compact segment sampling methods. Blindness, VI and severe visual impairment (SVI) were defined as per the WHO guidelines and Indian definitions.

**Results:** Based on a prior enumeration, 7281 (97.1%) subjects were enrolled (mean age = 61.0±7.9 years). Based on the presenting visual acuity (PVA), the prevalences of VI, SVI and blindness were 16.9% (95% CI: 15.7–18.1), 2.9% (95% CI: 2.5–3.4), and 2.3% (95% CI: 1.9–2.7), respectively. When based on the Pinhole corrected visual acuity (PCVA), the prevalences were lower in VI (6.2%, 95% CI: 5.4–6.9), SVI (1.5%, 95% CI: 1.2–1.9) and blindness (2.1%, 95% CI: 1.7–2.5). Refractive error was the major cause of VI (71.4%), whereas, cataract was the major cause of SVI and blindness (70.3%). Based on the PVA, the odds ratio (OR) of blindness increased in the age groups of 60–69 years (OR = 3.8, 95% CI: 2.8, 5.1), 70–79 years (OR = 10.6, 95% CI: 7.2, 15.3) and 80 years and above (OR = 30.7, 95% CI: 19.2, 49). The ORs were relatively higher in females (OR = 1.3, 95% CI: 1.0, 1.6) and illiterate subjects (OR = 4.3, 95% CI: 2.2, 8.5), but lower in those wearing glasses (OR = 0.2, 95% CI: 0.1, 0.4).

**Conclusions:** This is perhaps the first study to assess the prevalence of blindness and VI in these tribal regions and the majority of the causes of blindness and SVI were avoidable (88.5%). These findings may be useful for planning eye care services in these underserved regions.

**Introduction**

Recent estimates show that there are 324 million people who are either blind or visually impaired in the world and that the burden of blindness and visual impairment (VI) is disproportionately clustered in the developing countries, including India [1]. With 8 million blind people and 62 million VI, India shares almost a quarter of the entire global burden of blindness and VI [1]. Although several prevalence of blindness studies have been reported in Indian populations, [2–9] there are limited studies in tribal populations, who are considered the “under-served of the under-served” [10].

India has a large and diverse tribal population, a category formally recognized by the Indian constitution. Tribal communities are characterized by their economic under-development, distinct cultural heritage and geographic isolation [11]. Areas that historically had high tribal populations are formally recognized by the Integrated Tribal Development Agency (ITDA), which aims to develop these tribal areas. ITDA has recently granted funds to implement eye care services in these tribal areas. In order to...
adequately serve these populations, it was necessary to assess the burden of blindness and VI in these communities, along with their causes.

Earlier we reported the visual outcomes and risk factors for poor outcomes [12]. Herein we report the prevalence of blindness and visual impairment, as well as its causes and their associated risk factors in these three selected tribal areas. Additionally this data was compared with the prevalence and causes of blindness in other countries with low and middle-income settings.

**Methods**

The Ethics Committee of the L V Prasad Eye Institute, Hyderabad, India, approved this study and it was conducted in accordance with the tenets of the Declaration of Helsinki.

Prior to undertaking this study, all the procedures were explained in detail to each subject in presence of community heads of the villages. Subsequently, a written consent was obtained from all subjects with minimal level of literacy and thumb impression was obtained from those who did not have a formal education.

There are several areas within Andhra Pradesh (AP) that are formally recognized by the government as tribal areas. Three areas in AP as outlines in our previous study were enumerated [12].

The sampling strategy based on Rapid Assessment of Avoidable Blindness (RAAB) methodology [13] and details of the methodology have been described elsewhere [12]. The definitions of blindness and VI used in the study are both the World Health Organization (WHO) and Indian Ministry of Health (MoH) [14].

The definitions of refractive error, cataract and glaucoma was as defined earlier [12]. Any fundus pathology other than glaucoma was characterized as posterior segment pathology.

Additional information was collected on tribal status and literacy. Illiteracy was defined as self-report of not able to read and write.

*Table 1.Baseline characteristics of participants and non-participants.*

| Subjects               | Total        | Participants | Non-participants |
|------------------------|--------------|--------------|------------------|
| Age group              | N (%)        | N (%)        | N (%)            |
| 50–59                  | 3296 (44.0)  | 3216 (44.2)  | 80 (36.5)        |
| 60–69                  | 2877 (38.4)  | 2770 (38)    | 107 (48.9)       |
| 70–79                  | 1082 (14.4)  | 1058 (14.5)  | 24 (11.0)        |
| ≥ 80                   | 245 (3.3)    | 237 (3.3)    | 8 (3.7)          |
| Mean age (SD)          | 61.0 (7.9)   | 61.0 (7.9)   | 61.4 (7.2)       |
| Gender                 |              |              |                  |
| Male                   | 3324 (44.3)  | 3216 (44.2)  | 105 (48.0)       |
| Female                 | 4176 (55.7)  | 4062 (55.8)  | 114 (52.1)       |
| Literacy               |              |              |                  |
| Literate               | 873 (11.6)   | 866 (11.9)   | 7 (3.20)         |
| Illiterate             | 6627 (88.4)  | 6415 (88.1)  | 212 (96.8)       |
| Tribal versus non-tribal|              |              |                  |
| Non Tribal             | 4547 (60.6)  | 4429 (60.8)  | 118 (53.9)       |
| Tribal                 | 2953 (39.4)  | 2852 (39.2)  | 101 (46.1)       |

SD: Standard Deviation.

doi:10.1371/journal.pone.0100644.t001

*Table 2. Prevalence of Blindness, SVI and VI based on presenting and Pinhole-corrected visual acuity.*

| Presenting visual acuity | Total | Male | Female | Total | Pinhole corrected visual acuity (pin-hole) |
|--------------------------|-------|------|--------|-------|-------------------------------------------|
| N                        |       |      |        |       | N                                         |
| VI (6/18–6/60)           |       |      |        |       | SVI (6/60–3/60)                           |
| Blindness (3/60)         |       |      |        |       | N                                         |
| % (95% CI)               |       |      |        |       | % (95% CI)                                |
| Total                    | N     |      |        |       | N                                         |
| Non Tribal               | 3219  | 579  | 18.0 (16.5–19.5) | 94 | 2.9 (2.3–3.5)                           |
| Tribal                   | 4062  | 119  | 2.9 (2.3–3.5)     | 114 | 19.9 (17–23)                           |
| Total                    | 7281  | 1228 | 16.9 (15.7–18.1)  | 213 | 31.8 (23–39)                           |
| Pinhole corrected visual acuity (pin-hole) N |       |      |        |       | N                                         |
| Non Tribal               | 3219  | 218  | 6.8 (5.7–7.9)     | 47 | 15.6 (10–21)                           |
| Tribal                   | 4062  | 230  | 5.7 (4.8–6.5)     | 65 | 16.6 (11–21)                           |
| Total                    | 7281  | 448  | 6.2 (5.4–6.9)     | 112 | 15.6 (12–19)                           |

SVI: Visual Impairment; SVI: Severe Visual Impairment; CI: Confidence Interval.

doi:10.1371/journal.pone.0100644.t002
Standard training and Inter Observer Variation Test (IOVT) was performed for each of the three teams for measurement of visual acuity (VA), lens examination and causes of blindness and VI to ensure acceptable agreement (Kappa value \(0.6\)). IOVT was conducted on 28 subjects by each of the three teams. IOVT for VA testing was conducted on ophthalmic assistants and for clinical findings, on ophthalmologists participating in the survey. IOVT was also done during the course of study for the measurement of VA, lens examination and to study the causes of blindness and VI in 6 preselected clusters (2 in each area). All subjects with PVA \(6/18\) in either eye, all subjects with previous cataract surgery and 10% of normal subjects were tested by the ophthalmic assistants for VA testing and by ophthalmologist for clinical findings. A total of 114 subjects were tested for IOVT and it showed a kappa value of more than 0.6. Before the start of main study, a pilot study was also done in a rural area and a total of 51 persons were examined.

All subjects aged \(\geq 50\) years in the population in the research area, residing in the village for the last 6 months and willing to give informed consent were selected for the study. All protocols followed the standard RAAB manual [13].

STATA version 11 was used to analyze the data [15]. The prevalence of blindness, SVI and VI by presenting and pinhole-corrected visual acuity were calculated. Risk factors for VI and < 6/60 (blindness using the Indian definition) were assessed using univariable and multivariable logistic regression. Multi-collinearity between variables was assessed looking at the variance inflation factor and calibration of the models were assessed by the Hosmer-Lemeshow test for goodness of fit [16].

**Results**

Overall 7281/7500 (97.1%) individuals were examined. Among the remaining, 154 (2.1%) were not available, 49 (0.7%) refused and 16 (0.2%) were unable to communicate. There was no significant difference in mean ages (\(p = 0.46\)) and gender (\(p = 0.3\)) between participants and non-participants (Table 1).

Based on PVA, the prevalence of VI was 16.9% (95% CI: 15.7–18.1), SVI was 2.9% (95% CI: 2.5–3.4), and blindness was 2.3% (95% CI: 1.9–2.7). The prevalence of blindness as per the Indian definition was 5.2 (95% CI: 4.6–5.9). Based on PCVA, the prevalence of VI was 6.2% (95% CI: 5.4–6.9), SVI was 1.5% (95% CI: 1.2–1.9), and blindness was 2.1% (95% CI: 1.7–2.5). The prevalence of blindness as per the Indian definition was 3.6 (95% CI: 3.1–4.2) (Table 2).

Based on PVA and PCVA, the odds of VI and blindness (Indian definition) increased with age and illiteracy. Additionally, the odds of blindness were significantly higher in female subjects. Based on PVA, odds of VI and blindness were lower in those wearing glasses, and Area 3 had lower odds of VI (Tables 3 and 4).

Refractive error (including uncorrected aphakia) was the major cause of VI (71.4%) and cataract was major cause of SVI and blindness (70.3%). Together, posterior segment disorders (including glaucoma) caused 4.2% of VI and 11.6% SVI and blindness. (Table 5)

| Table 3. Presenting Visual Acuity: Risk factors for VI, SVI and blindness. |
|-----------------|-----------------|-----------------|
| **Age group**   | **VI**          | **Blindness+ SVI** |
|                 | **Multivariate OR (95% CI)** | **Multivariate OR (95% CI)** |
| 50–59 Ref       | Ref             | Ref             |
| 60–69 2.84(2.4,3.35) | 3.77(2.77,5.13) |
| 70–79 4.80(3.94,5.84) | 10.56(7.22,15.45) |
| 80+ 7.27(5.14,10.3) | 30.72(19.24,49.04) |
| **Gender**      |                 |                 |
| Male Ref        | Ref             | Ref             |
| Female 0.93(0.81,1.07) | 1.28(1.01,1.61) |
| **Literacy**    |                 |                 |
| Literate Ref    | Ref             | Ref             |
| Illiterate 1.71(1.29,2.27) | 4.34(2.23,8.45) |
| **Tribal status** |                 |                 |
| Non–tribal Ref | Ref             | Ref             |
| Tribal 1.00(0.82,1.22) | 1.16(0.86,1.56) |
| **Area**        |                 |                 |
| 1 Ref           | Ref             | Ref             |
| 2 0.84(0.68,1.05) | 0.72(0.51,1.03) |
| 3 0.74(0.58,0.95) | 0.97(0.71,1.35) |
| **Use of glasses** |                 |                 |
| No Ref         | Ref             | Ref             |
| Yes 0.71(0.56,0.91) | 0.21(0.12,0.38) |
| **Goodness of fit ‘p’ value** | 0.302 | 0.6597 |

VI: Visual Impairment; SVI: Severe Visual Impairment; CI: Confidence Interval; Ref: Reference group; OR: Odds Ratio.

doi:10.1371/journal.pone.0100644.t003
There was no significant difference in the use of glasses between males and females (p = 0.273). However, use of glasses was significantly less likely in tribal subjects than non-tribal subjects (p < 0.001), illiterate than literate subjects (p < 0.001) and subjects residing in areas 2 and 3 to those residing in Area 1 (p < 0.001).

Discussion

This study was designed specifically to report the prevalence of blindness and VI in tribal areas in the state of AP and the observed prevalence compares favorably to other populations in India and neighboring countries found in the last decade. Using the same definition, the observed prevalence of blindness in this study is similar to the other studies in India [2,4,9] and neighboring countries like Nepal [17,18], Bangladesh [19] and Pakistan [20]. (Table 6) However, the prevalence is much lower than many other studies reported in India [3,6–8] and countries like Nepal [21] and Myanmar [22]. The observed prevalence is also lower than the two reported studies from tribal areas of India [10] and Pakistan [23] and was higher than some other studies from Nepal [24], Pakistan [25] and China [26] (Table 6). The potential causes for these observed differences are many; they may reflect regional differences in terms of availability of services, time periods when the studies were conducted, age groups included in the population, cultural beliefs for health-promoting behaviors, or, most simply, sampling variation in these studies. For instance, the national

| Table 4. Pinhole Corrected Visual Acuity: Risk factors for VI, SVI and Blindness. |
|---------------------------------|----------------------------------|----------------------------------|
|                                 | VI Multivariate OR (95% CI)     | Blindness + SVI Multivariate OR (95% CI) |
| Age group                       |                                 |                                 |
| 50–59                           | Ref                              | Ref                              |
| 60–69                           | 3.35 (2.5, 4.48)                 | 3.18 (2.14, 4.72)                |
| 70–79                           | 6.53 (4.72, 9.05)                | 9.34 (5.92, 14.72)               |
| 80+                             | 10.21 (6.64, 15.72)              | 22.89 (13.35, 39.25)             |
| Gender                          |                                 |                                 |
| Male                            | Ref                              | Ref                              |
| Female                          | 0.88 (0.71, 1.09)                | 1.45 (1.11, 1.88)                |
| Literacy                        |                                 |                                 |
| Literate                        | Ref                              | Ref                              |
| Illiterate                      | 2.18 (1.46, 3.25)                | 4.31 (1.84, 10.09)               |
| Tribal status                   |                                 |                                 |
| Non-tribal                      | Ref                              | Ref                              |
| Tribal                          | 1.08 (0.8, 1.45)                 | 1.37 (0.97, 1.92)                |
| Area                            | 0.0063                           | 0.2471                           |
| 1                               | Ref                              | Ref                              |
| 2                               | 0.71 (0.5, 1.01)                 | 0.75 (0.50, 1.13)                |
| 3                               | 1.31 (0.95, 1.79)                | 1.05 (0.73, 1.53)                |
| Goodness of fit ‘p’ value       | .1602                            | .7054                            |

VI: Visual Impairment; SVI: Severe Visual Impairment; CI: Confidence Interval; Ref: Reference group; OR: Odds Ratio.
doi:10.1371/journal.pone.0100644.t004

| Table 5. Causes of VI, SVI and blindness. |
|------------------------------------------|------------------------------------------|
| Cause                                    | VI N (%)                                | SVI + Blindness N (%)                  |
| Refractive Error                          | 869 (70.8)                              | 36 (9.5)                               |
| Cataract untreated                       | 287 (23.4)                              | 268 (70.3)                             |
| Aphakia uncorrected                      | 7 (0.6)                                 | 10 (2.6)                               |
| Surgical Complication(s)                 | 11 (0.9)                                | 4 (1.1)                                |
| Phthisis                                 | 0 (0.0)                                 | 4 (1.1)                                |
| Corneal scar                             | 2 (0.2)                                 | 15 (3.9)                               |
| Glaucoma                                 | 8 (0.7)                                 | 8 (2.1)                                |
| Other posterior segment diseases          | 44 (3.5)                                | 36 (9.5)                               |
| Total                                    | 1228                                    | 381                                    |

VI: Visual Impairment; SVI: Severe Visual Impairment.
doi:10.1371/journal.pone.0100644.t005
prevalence was a pooled prevalence from 16 districts of 15 states and the prevalence of individual districts was not reported [8]. This might obscure the variability within the regions. Similarly, the study in Bharatpur, Rajasthan was conducted a decade earlier than this study, and the differences in prevalence might be a reflection of the changing trends of blindness over time [6]. Additionally, we observed that the prevalence of presenting VI was a pooled prevalence from 16 districts of 15 states compared to other studies done in India and elsewhere, the region of Maharashtra [10], the Lumbini zone and Chetwan District of Nepal [18] and the national survey [8]. When compared to other studies done in India and elsewhere, the prevalences were highly variable [2–4,6,7,9,17,19,21,24–26] (Table 6), which could be due to the same reasons mentioned above.

Both univariable and multivariable analysis indicated older age to be a major risk factor for VI and blindness in PVA and PCVA. This is consistent to findings observed in other studies from India and adjoining developing nations [4,6–10,17,18,21,22,24,26,27] (Table 7). Additionally, females were more likely to be blind by PVA (OR 1.28, 95% CI: 1.01–1.61) and PCVA (OR 1.45, 95% CI: 1.11–1.89). These findings are however partially consistent with some studies [4,6,8,17,21,26], but not in others [7,9,10,24] (Table 7). While this disparity may be grossly attributed to different social experiences and/or different barriers to accessing eye care services, further studies are needed to understand the underlying causes.

Illiteracy was a significant risk factor for blindness and VI, based in PVA and PCVA. This seemed to be a general phenomenon as observed in other studies [4,6,7,9,18,21,22,24,26] (Table 7). Furthermore, we also observed that illiterate subjects were less likely to use glasses that is indicative of a major barrier to accessing eye care services. Whether this is due to poverty or lack of knowledge needs further exploration. It may be recommended that community programs should include illiteracy as a major consideration when planning for outreach activities.

Based on the PVA, the odds of VI was lower in Area 3 in a multivariable analysis. According to local sources, non-tribal subjects migrate to tribal areas to enjoy government-mandated benefits, and they preferentially inhabit areas with burgeoning local economies. Each area varied significantly with respect to the fraction of tribal population and literacy rates within it (p value < 0.001) and subjects in Area 3 had significantly higher literacy rates and a lower tribal population compared to other two areas (data not shown). Altogether, these findings indicate that Area 3 has possibly developed the most of the three areas, resulting in better quality of available and accessible services as compared to the other areas. Similarly, those wearing glasses were also at lower risk of blindness and VI based on PVA.

Interestingly, the ‘tribal’ status was not a risk factor for either VI or blindness by any definition indicating that these populations did not face any specific health disparity compared to the ‘non-tribes’. The poor eye health appeared to be characteristic of the areas sampled and not restricted to any specific group of people (i.e. tribal or non-tribal). Our findings could be further explained by the fact that both the tribal people and non-tribal people intermix in their daily life and hence, differences in lifestyle or behaviors that leading to a health disparity was unlikely.

While there has been substantial achievements in combating cataract and refractive error-related blindness due to planned eye care services, they still continue to be a major cause of blindness and VI in India and other developing countries (Table 8). The most sobering finding of this study, however, was that 82.4% of the presenting cases of blindness were treatable (untreated cataract, uncorrected aphakia, refractive error) and 6.1% preventable (corneal scars, surgical complications and phthisis). Moreover, we found that 11.6% of blindness was caused by posterior segment disorders (including glaucoma). This is consistent with some of the

### Table 6. Prevalence of blindness, SVI and VI in different studies in India and neighboring countries.

| Country (Year of survey) | Region | Age group | Number examined (%) | Blindness (95% CI) | SVI (95% CI) | VI (95% CI) |
|--------------------------|--------|-----------|---------------------|--------------------|-------------|-------------|
| India (1998) [6]         | Rajasthan (Bharatpur) | > = 50 | 4284 (90.6) | 8.9 (7.2–10.5) | 3.1 (2.3–3.8) | 24.3 (23.0–25.6)** |
| India (1999) [9]         | Rural South India (Sivaganga) | > = 50 | 4642 (91.4) | 4.0 (3.5–4.5) | 2.0 (1.4–2.7) | 28.5 (27.2–29.8)** |
| India (2007) [8]         | National (16 districts of 15 states) | > = 50 | 40447 (94.7) | 3.6 (3.3–3.9) | 4.4 (4.1–4.8) | 16.8 (16.0–17.5) |
| India (2007) [7]         | Gujarat | > = 50 | 4738 (91.9) | 4.3 (3.5–5.1) | 2.6 (1.8–3.4) | 29.3 (27.5–31.2) |
| India (2011) [2]         | Kamataka (Kolar) | > = 50 | 2907 (95.3) | 3.9 (2.7–5.1) | 3.5 (2.4–4.6) | 10.4 (8.77–12.08) |
| India (2009) [10]        | Maharashtra (Nandurbar) | > = 50 | 2004 (87.2) | 1.87 (1.32–2.42) | 6.72 (5.7–7.74) | 19 (17.4–20.6) |
| India (2010) [4]         | Prakasam Weavers South | > = 40 | 2848 (94) | 2.9 (2.3–3.5) | NA | 9.4 (8.3–10.5) |
| Nepal (2002) [24]        | Gandaki Zone | > = 45 | 5002 (85.3) | 1.4 (1.1–1.8) ** | 1.2 (0.9–1.5)** | 8.9 (8.1–9.7)** |
| Nepal (2006) [18]        | Lumbini Zone & Chitwan District | > = 50 | 5138 (87) | 2.3 (1.7–2.8) | 2.3 (1.5–3.2) | 16 (15.0–17.0)** |
| Nepal (2006) [21]        | Rautahat District | > = 50 | 4717 (85.3) | 6.9 (5.5–8.3) | 10.5 (9.3–11.8) | 25.6 (24.4–26.9)** |
| Nepal* [17]              | Kamali Zone | > = 50 | 1174 (97.8) | 3.4 (2.4–4.4) | 2.1 (1.4–3.1)** | 9.7 (8.1–11.5)** |
| Bangladesh (2005) [19]   | Sathkhira District | > = 50 | 4868 (91.9) | 2.9 (2.4–3.5) | 1.6 (1.2–2.0) | 8 (7.5–9.3) |
| Pakistan* [23]           | Tribal Area (Orakazi Agency) | > = 50 | 1549 (96.8) | 5.9 (4.7–7.0) | NA | NA |
| China (2006) [27]        | Kunming | > = 50 | 2588 (93.8) | 2.7 (2.1–3.4) ** | 3 (2.2–3.8) | 9.1 (7.5–10.7) |
| China (2006) [26]        | Rural (9 Provinces) | > = 50 | 45747 (94.7) | 3.6 (3.3–3.9) | 4.4 (4.1–4.8) | 16.8 (16.0–17.5) |
| Myanmar (2005) [22]      | Meiktila (Rural Myanmar) | > = 40 | 2076 (83.6) | 8.1 (6.5–9.9) | NA | 32.9 (27.7–38.1) |

*: Year of study not available; CI: Confidence Interval; **: Confidence Interval calculated using binomial proportions; SVI: Severe Visual Impairment; VI: Visual Impairment; NA: Data not available. doi:10.1371/journal.pone.0100644.t006
Table 7. The risk factors for Blindness and VI based on presenting visual acuity across different studies in India and neighbouring countries.

| Country (Year) | Region | Age group | OR (95% CI) | OR (95% CI) | OR (95% CI) | OR (95% CI) |
|----------------|--------|-----------|-------------|-------------|-------------|-------------|
|                |        | Age       | Female gender | Illiteracy | Rural location |
| India (2001) [6] | Rajasthan (Bharatpur) | 50–59 | Ref | 1.6 (1.3–2) | 2.8 (2.0–3.7) | 1.7 (1.0–2.8) |
|                |        | 60–69 | 3.8 (2.8–5.1) |            |             |             |
|                |        | > = 70 | 12.8 (9.6–17.1) |            |             |             |
| India (2002) [9] | Rural South India (Sivaganga) | 50–59 | Ref | 1.1 (0.8–1.4) | 2.6 (1.7–4.0) | 1.0 (0.6–1.7) |
|                |        | 60–69 | 2.6 (1.9–3.6) |            |             |             |
|                |        | > = 70 | 5.6 (4.0–8.0) |            |             |             |
| India (2008) [8] | National (16 districts of 15 states) | 50–54 | Ref | 1.56 (1.45–1.72) | NA | 1.2 (1.1–1.33) |
|                |        | 55–59 | 1.91 (1.54–2.38) |            |             |             |
|                |        | 60–64 | 3.65 (2.99–4.45) |            |             |             |
|                |        | 65–69 | 4.92 (4.03–6.01) |            |             |             |
|                |        | > = 70 | 7.42 (6.07–9.06) |            |             |             |
| India (2010) [7] | Gujarat | 50–59 | Ref | 0.92 (0.68–1.23)\* | 0.22 (0.16–0.31)* | 0.7 (0.41–1.2)\$ |
|                |        | 60–69 | 2.7 (2.3–3.6) |            |             |             |
|                |        | > = 70 | 5.9 (4.2–8.3) |            |             |             |
| India (2012) [10] | Maharashtra (Nandurbar) | NA | + | 1.5 (0.75–3.75) | NA | NA |
| India (2013) [4] | Prakasam Weavers South | 40–49 | Ref | 1.3 (1.0–1.7) | 1.7 (1.3–2.2)* | NA |
|                |        | 50–59 | 3.5 (2.5–5.2) |            |             |             |
|                |        | 60–69 | 8.7 (5.9–12.7) |            |             |             |
|                |        | > = 70 | 22.4 (15.0–33.5) |            |             |             |
| Nepal (2006) [24] | Gandaki Zone | 45–49 | Ref | 1.1 (0.8–1.7) | 3.5 (1.7–7.1) | NA |
|                |        | 50–60 | 1.7 (0.6–4.9) |            |             |             |
|                |        | 61–70 | 4.7 (1.8–12.4) |            |             |             |
|                |        | > = 70 | 24 (9.5–60.3) |            |             |             |
| Nepal (2009) [18] | Lumbini Zone & Chitwan District | 50–59 | Ref | NA | 2.9 (1.6–5.1) | NA |
|                |        | 60–69 | 3.2 (2.2–4.6) |            |             |             |
|                |        | > = 70 | 6.1 (4.1–9.1) |            |             |             |
| Nepal (2010) [21] | Rautahat District | 50–59 | Ref | 1.4 (1.1–1.7) | 2.0 (1.5–2.8) | NA |
|                |        | 60–69 | 2.7 (2.3–3.1) |            |             |             |
|                |        | > = 70 | 6.6 (5.4–8.0) |            |             |             |
| Nepal (2012) [17] | Karnali Zone | + | ++ | NA | NA | NA |
| China (2008) [27] | Kunming | + | NA | NA | 2.9 (1.5–5.3) | NA |
| China (2010) [26] | Rural (9 Provinces) | 50–59 | Ref | 1.5 (1.31–1.72) | 0.78 (0.62–0.98)* | NA |
|                |        | 60–69 | 2.6 (2.03–3.35) |            |             |             |
|                |        | 70–79 | 8.96 (6.95–11.6) |            |             |             |
|                |        | > = 80 | 29.4 (22.2–39.0) |            |             |             |
| Myanmar (2007) [22] | Meiktila (Rural Myanmar) | 40–49 | Ref | 2.8 (1.3–5.2) | 1.3 (0.8–1.8) | 1.4 (1.0–2.0) | NA |
|                |        | 60–69 | 6.5 (3.4–12.3) |            |             |             |
|                |        | > = 70 | 11.9 (6.3–22.5) |            |             |             |

OR: Odds Ratio; Ref: Reference Group; CI: Confidence Interval;\:
\* Reference group: Female;
\# Reference group: Illiterate;
\$: Reference group: Rural location;
\#: Primary education;
\$: Secondary education;
\+: Higher with increasing age (Odds ratio and 95% CI not available);
\++: Higher in females (Odds ratio and 95% CI not available).
doi:10.1371/journal.pone.0100644.t007
recent studies from India that exhibited an increase in the prevalence of posterior segment disorders [2,7]. This fraction is fairly substantial, and it highlights the importance of a dilated fundus examination to assess the cause of blindness in populations.

The major strengths of this study pertain to the fact that it adhered to the RAAB methodology, and had a very high response rate (97.1%). One of the methodological weaknesses of the study was that VI / blindness was determined based on visual acuity and visual fields defects were not included. This may potentially underestimate the prevalence of VI / blindness. Similarly, the prevalence and causes of blindness and VI in those below 50 years could not be estimated. Also, as age and gender were not adjusted for prevalence estimates, it is possible that there could be demographic differences from other studies. As the RAAB methodology assigns primary cause of vision loss to the disorder that can be most easily treated, this study is likely to underestimate the presence of co-morbid causes of vision loss. Additionally, subjects who were illiterate participated in the study at lower rates than literate subjects, suggesting that our estimate of prevalence of blindness is an underestimate. This bias is mitigated by the fact that the study had a very high response rate (97.1%), which is a major strength of this study.

Nevertheless, this study provides an overview for understanding the burden and distribution of blindness and VI and their associated risk factors in these underserved areas. Further research should be aimed at analyzing the issues underlying patients’ attitudes, availability, accessibility and affordability of services that affect blindness and VI in these communities.

Acknowledgments

We wish to thank Prof Jill Keeffe for her critical review of the data and providing valuable inputs for the manuscript. We also would like to acknowledge all the subjects who volunteered to be part of the study.

Author Contributions

Conceived and designed the experiments: RCK SSE BKG SR PKR. Performed the experiments: RCK SSE BKG SR PKR. Analyzed the data: NS PK GPSS SC RCK. Contributed reagents/materials/analysis tools: NS PK GPSS SC RCK. Wrote the paper: NS PK GPSS SC RCK. Data management: RCK SSE BKG SR.

References

1. Pascolini D, Mariotti SP (2012) Global estimates of visual impairment: 2010. The British journal of ophthalmology 96: 614–618.
2. Guruprasad BS, Krishnamurthy D, Narendra DP, Ranganath BG, Shamanna RB (2013) Changing Scenario of Cataract Blindness in Kolar District, Karnataka, South India. The Utility of Rapid Assessment of Avoidable Blindness in Reviewing Programs. Ophthalmic Epidemiology 20: 89–95.
3. Marmamula S, Madala SR, Rao GN (2011) Rapid assessment of visual impairment (RAVI) in marine fishing communities in South India - study protocol and main findings. BMC Ophthalmology 11: 26.
4. Marmamula S, Narsaiah S, Shekhar K, Khanna RC (2013) Visual Impairment among Weaving Communities in Prakasam District in South India. PLoS ONE 8: e53924.
5. Marmamula S, Narsaiah S, Shekhar K, Khanna RC; Rao GN (2013) Visual impairment in the South Indian state of Andhra Pradesh: Andhra Pradesh - rapid assessment of visual impairment (AP-RAVI) project. PLoS One 8: e70120.
6. Murthy GV, Gupta S, Ellwein LB, Munoz SR, Bachani D, et al. (2001) A population-based eye survey of older adults in a rural district of Rajasthan: I. Central vision impairment, blindness, and cataract surgery. Ophthalmology 108: 670–675.
7. Murthy GVS, Vashist P, John N, Pohkarel G, Ellwein LB (2010) Prevalence and Causes of Visual Impairment and Blindness in Older Adults in an Area of India with a High Cataract Surgical Rate. Ophthalmic Epidemiology 17: 185–195.
8. Neena J, Rachel J, Praveen V, Murthy GVS, Group fRIS (2008) Rapid Assessment of Avoidable Blindness in India. PLoS ONE 3: e2867.

Table 8. Causes of blindness, SVI and VI in different studies in India and neighbouring countries.

| Country (Year) | Region | Causes of blindness (%) | Causes of SVI (%) | Causes of VI (%) |
|---------------|--------|--------------------------|-------------------|------------------|
| India (2001) [6] | Rajasthan (Bharatpur) | Cataract (67.5) and uncorrected aphakia including RE (18.4) in at least one eye | NA | NA |
| India (2002) [9] | Rural South India (Sivaganga) | Cataract (69.4), RE including uncorrected aphakia (35.6) in one or both eyes* | - | NA |
| India (2008) [8] | National (16 districts of 15 states) | Cataract (77.5)* | - | Cataract (58.1), RE (32.9) |
| India (2010) [7] | Gujarath | Cataract (82.6), posterior segment disease (8.9)* | - | Cataract (50.3), RE (35.4) |
| India (2012) [2] | Karnataka (Kolar) | Cataract (74.6), posterior segment (8.8) | Cataract (73.3), RE (11) | RE (56.1), cataract (35.3) |
| India (2012) [10] | Maharsahtra (Nandurbar) | Cataract (76) | NA | NA |
| India (2013) [4] | Prakasam Weavers South | Cataract (62.6), RE (20.6) | NA | RE (73.2), cataract (18.6) |
| Nepal (2006) [24] | Gandaki Zone | Cataract (64.5), RE (13.2) | NA | NA |
| Nepal (2009) [18] | Lumbini Zone and the Chitwan District | Cataract (48.1); RE (31.4), retinal disorder (4), corneal opacity (3.8) | NA | NA |
| Nepal (2010) [21] | Rautahat District | Cataract (85.9), RE (7.3) | NA | NA |
| Nepal (2012) [17] | Karnali Zone | Cataract (67.5) | Cataract (96) | RE (36.8), cataract (58.8) |
| Bangladesh (2006) [19] | Sathkira District | Cataract (79.0), posterior segment (13.3) | Cataract (78.2), posterior segment (15.4) | RE (52.9), cataract (41.9) |
| Pakistan (2006) [23] | Tribal Area (Orakazi Agency) | Cataract (82.4) | NA | RE (83.3) |
| China (2008) [27] | Kunming | Cataract (63.2), trachomatous scar (14.7), glaucoma (7.4) | Cataract (71.4); other posterior segment (7.8) | Cataract (51.7), RE (36) |
| Myanmar (2007) [22] | Meiktila (Rural Myanmar) | Cataract (53.0) angle closure glaucoma (9.6) | NA | NA |

*: For both Blindness and Severe Visual Impairment; RE: Refractive error; SVI: Severe Visual Impairment; VI: Visual Impairment; NA: Data not available. doi:10.1371/journal.pone.0100644.t008
9. Thulasiraj RD, Rahamathulla R, Saraswati A, Selvaraj S, Ellwein LB (2002) The Sivaganga eye survey: I. Blindness and cataract surgery. Ophthalmic Epidemiology 9: 299–312.
10. Khandekar R, Deshpande M, Dhake P, Dole K (2011) Prevalence and causes of avoidable blindness and severe visual impairment in a tribal district of Maharashtra, India. Oman Journal of Ophthalmology 4: 129.
11. Ministry of Tribal Affairs website. Available: http://www.tribal.nic.in. Accessed 7th July, 2013.
12. Khanna RC, Pallerla SR, Eeda SS, Gudapati BK, Cassard SD, et al. (2012) Population based outcomes of cataract surgery in three tribal areas of Andhra Pradesh, India: risk factors for poor outcomes. PLoS ONE 7: e35701.
13. Community Eye Health Journal website. Available: http://www.cebjournal.org/files/raab/RAABManualVFPV4.02.pdf. Accessed, 6th July, 2013.
14. Blind People’s Association India website. Available: http://www.bpaindia.org/VIB Chapter-I.pdf. Accessed 6th July, 2013.
15. StataCorp. 2009. Stata Statistical Software: Release 11. College Station, TX: StataCorp LP.
16. Hosmer D, Lemeshow S (2000) Applied Logistic Regression Analysis John Wiley & Sons.
17. Dulal S, Sapkota YD (2012) Prevalence of blindness and visual impairment and its causes among people aged 50 years and above in Karnali Zone, Nepal. Nepalese journal of ophthalmology: a biannual peer-reviewed academic journal of the Nepal Ophthalmic Society, NEPJOH 4: 262–267.
18. Shrivastva A, Kandel RP, Sharma MK, Sapkota YD, Aghajanian J, et al. (2010) Blindness prevalence and cataract surgical coverage in Lumbini Zone and Chetwan District of Nepal. British Journal of Ophthalmology 94: 161–166.
19. Wadh D (2006) Rapid assessment of avoidable blindness and needs assessment of cataract surgical services in Satkhira District, Bangladesh. British Journal of Ophthalmology 90: 1225–1229.
20. Shadik SP, Aziz TM (2005) Rapid assessment of cataract surgical services in age group 50 years and above in Lower Dir District Malakand, Pakistan. Journal of the College of Physicians and Surgeons–Pakistan: JCPSP 15: 145–146.
21. Sapkota YD, Sunuwar M, Naito T, Akura J, Adhikari HK (2010) The Prevalence of Blindness and Cataract Surgery in Rautahat District, Nepal. Ophthalmic Epidemiology 17: 82–89.
22. Cassou RJ, Newsland HS, Muecke J, McGovern S, Durkin S, et al. (2007) Prevalence and Causes of Visual Impairment in Rural Myanmar. Ophthalmology 114: 2302–2308.
23. Anjum KM, Qureshi MB, Khan MA, Jan N, Ali A, et al. (2006) Cataract blindness and visual outcome of cataract surgery in a tribal area in Pakistan. British Journal of Ophthalmology 90: 133–138.
24. Sapkota YD (2006) Prevalence of blindness and cataract surgery in Gandaki Zone, Nepal. British Journal of Ophthalmology 90: 411–416.
25. Ahmad K, Khan MD, Qureshi MB, Munani S, Shah RA, et al. (2005) Prevalence and Causes of Blindness and Low Vision in a Rural Setting in Pakistan. Ophthalmic Epidemiology 12: 19–23.
26. Zhao J, Ellwein LB, Cui H, Ge J, Guan H, et al. (2010) Prevalence of vision impairment in older adults in rural China: the China Nine-Province Survey. Ophthalmology 117: 409–416, 416 e401.
27. Wu M, Yip JL, Kuper H (2008) Rapid assessment of avoidable blindness in Kunming, China. Ophthalmology 115: 969–974.