BMJ Open

Time trends, associations and prevalence of blindness and vision loss due to glaucoma: an analysis of observational data from the Global Burden of Disease Study 2017

Yi Sun ,[1] Aiming Chen,[2] Minjie Zou ,[3] Yichi Zhang ,[4] Ling Jin,[3] Yi Li,[5] Danying Zheng,[3] Guangming Jin ,[3] Nathan Congdon[3,6,7]

To cite: Sun Y, Chen A, Zou M, *et al*. Time trends, associations and prevalence of blindness and vision loss due to glaucoma: an analysis of observational data from the Global Burden of Disease Study 2017. *BMJ Open* 2022;**12**:e053805. doi:10.1136/bmjopen-2021-053805

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-053805).

YS, AC and MZ are joint first authors.

Received 26 May 2021
Accepted 22 October 2021

For numbered affiliations see end of article.

Correspondence to
Dr Guangming Jin; jingm@mail2.sysu.edu.cn and Dr Danying Zheng; zhengdyy@163.com

ABSTRACT

Objective To estimate global prevalence of blindness and vision loss caused by glaucoma, and to evaluate the impact of socioeconomic factors on it.

Design A population-based observational study.

Setting The prevalence of blindness and vision loss due to glaucoma were obtained from the Global Burden of Disease Study 2017 database. The Human Development Index (HDI), inequality-adjusted HDI and other socioeconomic data were acquired from international open databases.

Main outcome measures The prevalence of blindness and vision loss due to glaucoma by age, gender, subregion and Socio-Demographic Index (SDI) levels. Multiple linear regression analysis was performed to explore the associations between the prevalence and socioeconomic indicators.

Results The overall age-standardised prevalence of blindness and vision loss due to glaucoma worldwide was 81.5 per 100 000 in 1990 and 75.6 per 100 000 in 2017. In 2017, men had a higher age-standardised prevalence than women (6.07% vs 5.42%), and the worldwide prevalence increased with age, from 0.5 per 100 000 in the 45–49 year age group to 112.9 per 100 000 among those 70+. Eastern Mediterranean and African regions had the highest prevalence during the whole period, while the Americas region had the lowest prevalence. The prevalence was highest in low-SDI and low-income regions while lowest in high-SDI and high-income regions over the past 27 years. Multiple linear regression showed cataract surgery rate (β=−0.01, p=0.009), refractive error prevalence (β=−0.03, p=0.024) and expected years of schooling (β= -8.33, p=0.035) were associated with lower prevalence, while gross national income per capita (β=0.002, p<0.001) was associated with higher prevalence.

Conclusions Lower socioeconomic levels and worse access to eyecare services are associated with higher prevalence of glaucoma-related blindness and vision loss. These findings provide evidence for policy-makers that investments in these areas may reduce the burden of the leading cause of irreversible blindness.

Strengths and limitations of this study

- This study provided useful data for policy-makers to enhance the management of glaucoma.
- The burden of specific type of glaucoma (open vs closed angle) was not reported which may limit the thorough understanding of the disease burden due to glaucoma.
- Data for two countries (approximately 1%) could not be obtained in the Global Burden of Disease 2017 database; the completeness of the study could be affected by unavailability of data from the above two countries to some extent.

INTRODUCTION

Glaucoma is the leading cause of irreversible blindness worldwide. In 2020, 4.13 million people aged 50 years and older suffered moderate and severe vision impairment, and 3.6 million were blind due to glaucoma.[1] In 2020, glaucoma caused 11% of all global blindness in adults aged 50 years and older.[1] It is of urgent importance to reduce the prevalence of vision loss caused by glaucoma.

The prevalence of glaucoma varies among different nations and regions. It appears to be highest among persons of African descent (ranging from 6.5% to 7.3%),[2 3] followed by East Asian populations (ranging from 2.59% to 3.54%).[4–6] This may be compared with figures from European-derived populations, which have been reported to fall below 2.0%.[7 8] Glaucoma prevalence in all these populations appears to be increasing with ageing of the global population.[2 4 9–11] The burden of visual impairment from glaucoma may generally be expected to follow the rising prevalence. Although data on the global prevalence of glaucoma vision loss are available,[1] its prevalence in regions with different income levels remains unknown.

The association between disability-adjusted life-years of glaucoma and socioeconomic development has been investigated,[12] and the inconsistent association between the prevalence of glaucoma and socioeconomic status has been described.[13–15] But the relationship between the prevalence of blindness and vision loss due to glaucoma and various socioeconomic indicators remains unclear. Hence, the question of whether socioeconomic factors affect the prevalence of blindness and vision loss due to glaucoma should be answered because this is crucial for policy-making and programme delivery in order to reduce the disease burden.

The Global Burden of Disease (GBD) 2017 study, which obtained data from censuses, household surveys, civil registration and vital statistics, disease registries, health service use and so on, quantified health loss across 359 diseases and injuries for 195 countries and territories up to 2017 and provides a shared database for evaluating the burden of blindness and vision loss caused by glaucoma and the variation in prevalence among different countries and regions. This study was conducted to further clarify this public health issue.

MATERIALS AND METHODS

Data sources

In this population-based observational study, the main outcome was prevalence of blindness and vision loss caused by glaucoma. Methods to compute prevalence have been described previously for the GBD 2015 study.[16] The following GBD 2017 data on glaucoma in each country were extracted from the Global Health Data Exchange (GHDx) (http://ghdx.healthdata.org/gbd-results-tool): (1) age-specific prevalence per 100 000; (2) age-standardised prevalence per 100 000 stratified by World Bank regional income levels from 1990 to 2017; (3) age-standardised prevalence per 100 000 stratified by different WHO regions from 1990 to 2017; (4) and age-standardised prevalence per 100 000 stratified by Socio-Demographic Index (SDI) level from 1990 to 2017. The Human Development Index (HDI) of different countries was obtained from the Human Development Report 2016 (http://hdr.undp.org/en/data). Gross national income (GNI) per capita was available from the World Bank open database (http://data.worldbank.org/). Global maps were produced from a data visualisation tool available from the GHDx which is supported by the Institute for Health Metrics and Evaluation (https://vizhub.healthdata.org/gbd-compare/). Values for the cataract surgical rate (CSR) is based on a previously-published study.[17] Data on the number of physicians per 10 000 population were obtained from the United Nations Development Programme open database (http://hdr.undp.org/en/data).

Definitions

Blindness was defined as presenting visual acuity (PVA) <3/60 or visual field around central fixation <10%, while vision loss was defined as moderate and severe visual impairment (PVA <6/18, ≥3/60), based on the better eye.

SDI is a measure of sociodemographic development based on educational attainment, average income per capita and total fertility rate. SDI varies from 0 to 1, and a higher value suggests a higher educational attainment and per capita income, and a lower total fertility rate. Countries with low SDI, middle-low SDI, middle SDI, middle-high SDI and high SDI were classified according to their 2017 SDI values.

HDI is an indicator incorporating social and economic factors. It reflects living standards, health, and educational level of an individual country. Life expectancy, mean years of schooling, expected years of schooling and GNI per capita are the four components of HDI, which ranges from 0 (lowest socioeconomic level) to 1 (highest socioeconomic level). Based on HDI values, countries are divided into four categories: low (HDI <0.550), moderate (0.550–0.699), high (0.700–0.799) and very high (≥0.800).

Statistical analysis

The Wilcoxon signed rank test was conducted to evaluate the differences in prevalence between men and women, as well as the age-standardised prevalence among the World Bank income levels and SDI levels. A stepwise multiple linear regression analysis was performed to explore the influence of socioeconomic variables on the prevalence. Variables with $p<0.20$ were then included in the stepwise multiple linear regression model. A $p\leq0.05$ was considered statistically significant. Statistical analysis was performed using Stata MP V.15.1 (StataCorp). Figures were obtained via GraphPad Prism software V.5.01 (San Diego, California, USA).

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this study.

RESULTS

Trends in the worldwide prevalence of blindness and vision loss due to glaucoma from 1990 to 2017

The global distribution of the prevalence of blindness and vision loss due to glaucoma is illustrated in figure 1. The overall prevalence worldwide was 81.5 (95% CI 69.9 to 95.0) per 100 000 in 1990 and 75.6 (95% CI 65.0 to 88.1) per 100 000 in 2017. The age-standardised prevalence of cases per 100 000 in 2017 was highest in African region (171.5, 95% CI 146.9 to 200.2) and lowest in Region of the Americas (61.1, 95% CI 52.6 to 70.7) (figure 1A). In terms of annual change between 1990 and 2017, the greatest increase in the prevalence was in Côte d'Ivoire (108.3) per 100,000, while the greatest decrease was in Qatar (−167.1) per 100 000 (figure 1B).

Age-specific and gender-specific prevalence of blindness and vision loss due to glaucoma in 2017

As shown in figure 2, the prevalence of blindness and vision loss due to glaucoma in 2017 among men was

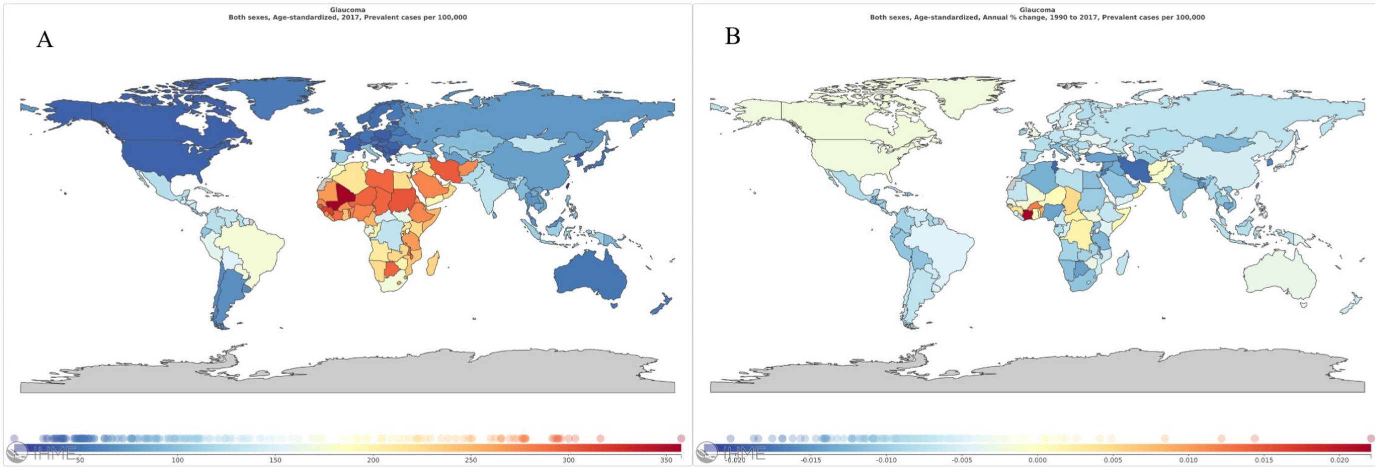

Figure 1 Global map of the prevalence of blindness and vision loss due to glaucoma from 1990 to 2017. (A) Age-standardised prevalence of cases per 100 000 in 2017. (B) Annual percentage change in the prevalence.

higher than that among women (men vs women : 6.07, 95% CI 3.79 to 8.81 vs 5.42, 95% CI 3.40 to 7.81) per 100 000. The prevalence for both sexes increased as age rose from 45 years to 95 years.

Prevalence of blindness and vision loss due to glaucoma by region, income level and SDI

Among the six WHO regions, the highest age-standardised prevalence of blindness and vision loss due to glaucoma was in the Eastern Mediterranean between 1990 and 2005 and in the African region between 2006 and 2017. By contrast, the region of the Americas had the lowest prevalence during the most period from 1990 to 2017 (63.0 per 100 000 in 1990, and 61.1 per 100 000 in 2017) (figure 3A; online supplemental table 1). With respect to income, the highest age-standardised prevalence was found in the World Bank's low-income regions (157.2 per 100 000 in 2017), while the lowest prevalence was found in high-income regions (42.7 per 100 000 in 2017) with statistical significance (p<0.001) (figure 3B). Similarly, the age-standardised prevalence was highest in low-SDI regions (111.2 per 100 000 in 2017) and lowest in high-SDI level regions (40.3 per 100 000 in 2017) (p<0.001) (figure 3C).

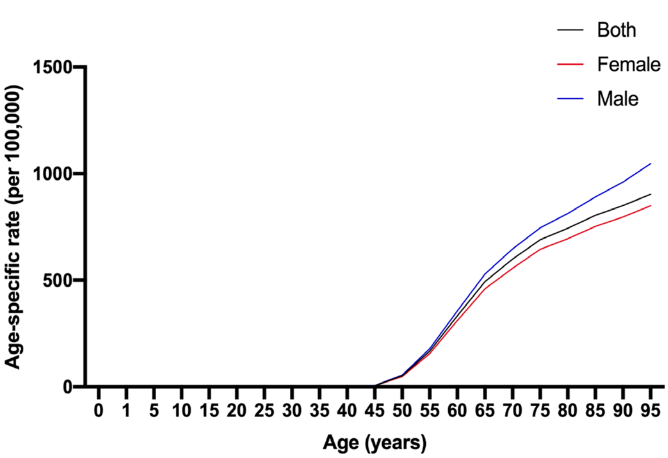

Figure 2 The prevalence of blindness and vision loss due to glaucoma by age and gender in 2017.

Association between socioeconomic variables and the prevalence of blindness and vision loss due to glaucoma

Linear regression analysis showed that the age-standardised prevalence of cataract was positively associated with the prevalence of blindness and vision loss due to glaucoma (β=0.03, 95% CI 0.02 to 0.40, p<0.001). CSR (β = −0.01, 95% CI −0.02 to −0.01, p<0.001), HDI (β = −238.5, 95% CI −301.0 to − 176.0, p<0.001), inequality-adjusted HDI (β = −217.3, 95% CI −266.1 to −168.4, p<0.001), SDI (β = −194.8, 95% CI −248.7 to −140.9, p<0.001) and physicians per 10, 000 population (β=−2.32, 95% CI −3.08 to −1.56, p<0.001) were negatively associated with the prevalence (table 1). Among these, 40.5% of the variation in age-standardised prevalence of blindness and vision loss due to glaucoma was attributed to inequality-adjusted HDI.

In stepwise multiple linear regression models adjusting for the age-standardised prevalence of cataract and refractive disorders, CSR, physicians per 10 000 population, mean years of schooling, GNI per capita, SDI, expected years of schooling and life expectancy at birth, GNI per capita (β=0.002, 95% CI 0.001 to 0.003, p<0.001) and age-standardised prevalence of cataract (β=0.03, 95% CI 0 to 0.05, p=0.044) were positively associated with prevalence of blindness and vision loss due to glaucoma. Conversely, age-standardised prevalence of refractive disorders (β=−0.03, 95% CI −0.05 to 0, p=0.024), CSR (β=−0.01, 95% CI −0.02 to 0, p=0.009) and expected years of schooling (β=−8.33, 95% CI −16.0 to −0.61, p=0.035) were negatively associated with prevalence of glaucomatous blindness and vision loss.

DISCUSSION

The current study analysed the global trends in the prevalence of blindness and vision loss due to glaucoma from 1990 to 2017, stratifying by gender, age and various socioeconomic indexes. The results showed that the worldwide age-standardised prevalence of blindness and vision loss due to glaucoma decreased from 81.5 per 100 000 in 1990 to 75.6 per 100 000 in 2017, and the prevalence increased

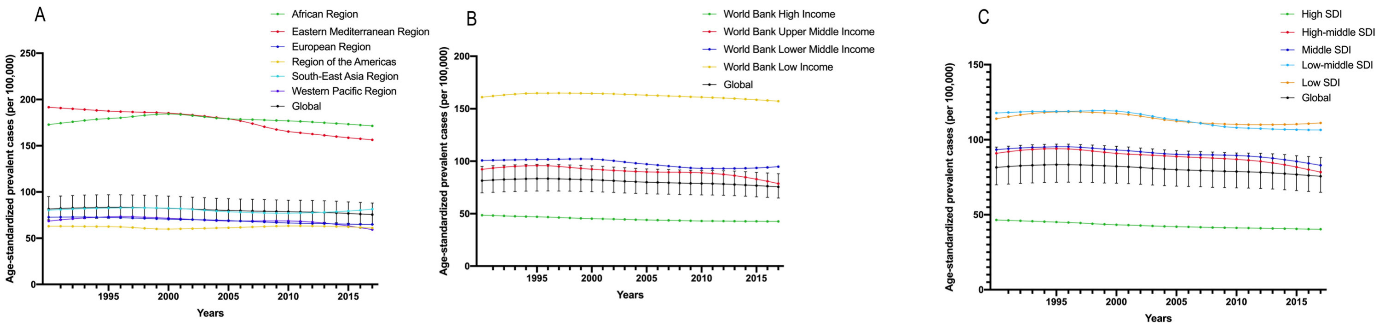

Figure 3 The age-standardised prevalence of blindness and vision loss due to glaucoma by region (A) and income level (B) and SDI level (C). SDI, Socio-Demographic Index.

with age and is higher among men. GNI per capita, expected years of schooling and age-standardised prevalence of cataract and refractive disorder was the associated factors with the prevalence of blindness and vision loss due to glaucoma when adjusting for the influence of socioeconomic factors and healthcare indictors.

Although the number of glaucoma patients aged 40–80 years was predicted to increase to 76 million in 2020,[5] and the number of blind or visually impaired due to glaucoma increased by 0.8 million and 2.3 million from 1990 to 2010, respectively,[18] age-standardised prevalence of blindness and vision loss due to glaucoma decreased between 1990 and 2017. This may be mainly explained by the revolution in diagnostic methods such as optical coherence tomography (OCT),[19] OCT angiography[20] and automated perimetry,[21] which has made early detection of asymptomatic glaucoma possible, at least in high-income countries, where access to such technology is better. The increased detection of glaucoma could lead to prevention of the progression of glaucoma through laser peripheral iridotomy or cataract extraction for angle-closure glaucoma and laser, topical medication or trabeculectomy for open-angle glaucoma. In low-resource settings, better access to cataract and refractive services may also have led to earlier detection and treatment of asymptomatic glaucoma.

The current study revealed that the prevalence of blindness and vision loss due to glaucoma was more common among men than women and the prevalence increased with age. This is consistent with Tham *et al*, who found men were more likely to have primary open angle glaucoma (POAG) than women and with various researchers who have reported that prevalence of POAG increased with age per decade.[5 22 23] In Asia, although the same conclusion was reached for open-angle glaucoma, men were less likely to have primary angle closure glaucoma (PACG) than women.[4 24 25] Higher ACG prevalence among women is thought to be due to their somewhat smaller eyes and more crowded anterior segments compared with men.[26 27] The underlying reasons for higher prevalence

Table 1 Linear regression analysis of the relationship between the variables and the prevalence of blindness and vision loss due to glaucoma in the world

	R^2	P value	Coefficient	Lower bound	Upper bound
Age-standardised prevalence of cataract	0.104	<0.001	0.03	0.02	0.40
Age-standardised prevalence of refractive disorders	0.000	0.908	−0.001	−0.01	0.01
CSR	0.209	<0.001	−0.01	−0.02	−0.01
HDI	0.248	<0.001	−238.5	−301.0	−176.0
Inequality-adjusted HDI	0.405	<0.001	−217.3	−266.1	−168.4
SDI	0.223	<0.001	−194.8	−248.7	−140.9
Physicians (per 10 000 people)	0.207	<0.001	−2.32	−3.08	−1.56
Multiple linear regression model*	0.475	<0.001			
Age-standardised prevalence of cataract	–	0.044	0.03	0	0.05
Age-standardised prevalence of refractive disorders	–	0.024	−0.03	−0.05	0
CSR	–	0.009	−0.01	−0.02	0
Expected years of schooling	–	0.035	−8.33	−16.0	−0.61
GNI per capita	–	<0.001	0.002	0.001	0.003

*Adjusted for age-standardised prevalence of cataract and refractive disorders, CSR, physicians per 10 000 people, mean years of schooling, GNI per capita, SDI, expected years of schooling and life expectancy at birth.
CSR, cataract surgery rate; GNI, gross national income; HDI, Human Development Index; SDI, Socio-Demographic Index.

of POAG among men is not well understood, and may be related to men's higher burden of cardiovascular disease and smoking, which is possibly associated with glaucoma.[28 29] ACG accounts for about 26% of all glaucoma cases in the world, while OAG accounts for about 74%,[30] and thus the overall burden of glaucoma among men is higher globally.

Regarding the association we observed between glaucomatous vision loss on the one hand and cataract and CSR on the other hand, the swelling of cataract can induce pupillary block, shallowness of the anterior chamber and the occlusion of the angle, leading to ACG. Cataract extraction has been proven to be effective in intraocular pressure control, particularly in eyes with narrow angles by widening the angle.[31–35] Similarly, increased CSR could reduce the prevalence of PACG, especially in people older than 70 years.[36] In addition to the above anatomical reasons, access to cataract services may serve as an opportunity for the detection of diseases such as glaucoma during preoperative screening. Therefore, more eye care programmes targeting cataract removal should be implemented to decrease the burden of glaucoma.

A stepwise multiple regression analysis showed that the prevalence of blindness and vision loss due to glaucoma was negatively associated with expected years of schooling. Higher educational levels likely lead to an increased awareness of health and better adherence with healthcare, leading in turn to earlier, more effective sight-saving treatment for glaucoma. In a study in India, education was the only variable significantly associated with awareness of glaucoma.[37]

In the multivariate linear regression analysis, there was also a significant association between refractive disorders and prevalence of blindness and vision loss due to glaucoma. Previous studies showed that the most common cause globally of low vision and blindness is uncorrected refractive error.[38 39] This is likely due to the positive association between glaucoma and myopia, the population-based evidence for which has been summarised elsewhere.[40]

Several limitations of this study must be pointed out. First, Data for two countries (approximately 1%) could not be obtained in the GBD 2017 database; the completeness of the study could be affected by unavailability of data from the above two countries or other subregions to some extent. Second, the incidence of various forms of glaucoma varies widely across different regions. But the type of glaucoma (open vs closed angle) was not reported specifically in the GBD database. Third, variations in socioeconomic development, race, genetics and systematic diseases between countries are inevitable and are not captured in our calculations. Despite these limitations, the study provides important information for policymakers to enhance the management of glaucoma, for example, investments in the lower socioeconomic areas, more uneventful cataract surgeries, control of refractive disorders and better education.

In summary, the worldwide age-standardised prevalence of blindness and vision loss due to glaucoma decreased slightly between 1990 and 2017. The prevalence increased with age and is higher among men. GNI per capita and age-standardised prevalence of cataract were positively associated with age-standardised prevalence of blindness and vision loss due to glaucoma, while age-standardised prevalence of refractive disorders, CSR and expected years of schooling were negatively associated with prevalence of glaucomatous blindness and vision loss. More resources delivered to underdeveloped countries and cataract outreach programmes can help to decrease the burden of glaucoma.

Author affiliations
[1]Department of Ophthalmology, Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, Guangdong, China
[2]Department of Pharmacy, The Fifth Affiliated Hospital, Sun Yat-sen University, Zhuhai, China
[3]State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangdong Provincial Key Laboratory of Ophthalmology and Visual Science, Guangzhou, China
[4]Department of Ophthalmology, Sun Yat-sen Memorial Hospital, Sun Yat-sen University, Guangzhou, China
[5]Department of Applied Biology and Chemical Technology, Hong Kong Polytechnic University, Hongkong, China
[6]Centre for Public Health, Queen's University Belfast, Belfast, UK
[7]Orbis International, New York, New York, USA

Acknowledgements We appreciate the work by Global Burden of Disease Study 2017 collaborators.

Contributors GJ acted as the guarantor. DZ, NC and GJ contributed to the conception and design of the study, and critical revision of the article. YS, MZ and AC contributed to the analysis and interpretation, and writing of the article. MZ, YZ AC and YL contributed to the data collection. YZ also contributed by writing of the article. GJ, LJ and DZ contributed to the administrative, technical or logistical support.

Competing interests None declared.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as online supplemental information. All data relevant to the study are included in the article. No additional data available.

ORCID iDs
Yi Sun http://orcid.org/0000-0003-1000-442X

Minjie Zou http://orcid.org/0000-0001-7706-6663
Yichi Zhang http://orcid.org/0000-0001-8948-466X
Guangming Jin http://orcid.org/0000-0001-9994-6338

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