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Article

Gender difference in cognitive health among older Indian adults: A cross-sectional multilevel analysis

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ABSTRACT

This study assesses the gender gap in cognitive health among older adults in India and examines the extent to which individual, household and state level characteristics contribute to the male-female difference in cognitive health. The study is based on 6548 women and men who participated in the WHO Study on Global AGEing and Adult Health conducted in six states in India during 2007–08. Multilevel ordinary least square regression was used to examine the gender difference in cognitive health, adjusting for individual, household, health behavior and state-level variables. A composite cognitive score (CCS) was calculated by combining *z*-scores of five individual cognitive tests. Results suggest that CCS is worse among women than among men after adjusting for individual and state level factors. The largest reduction in the gender gap in CCS was observed when adjusting for education, followed by other individual factors such as marital status, individual height, caste, religion, tobacco consumption and chronic health status. Although state level urbanization and female workforce participation rate were significantly associated with CCS, these characteristics did not contribute to the reduction of gender difference in CCS. This study extends the current knowledge of women's disadvantage in cognitive health, demonstrating that individual level characteristics remain key determinants of gender difference in cognition among older adults in India. Importantly, this relationship holds in the context of very large cross-state variations in cognitive health and its determinants.

1. Introduction

Cognitive health is one of the major factors determining the quality of life of older adults. Evidence from both developed and developing countries suggests that poor cognitive health is linked to several age-related morbidities, functional restrictions, poor mental state and poor quality of life among older adults (Cole & Dendukuri, 2003; Kalaria et al., 2008; Mather & Carstensen, 2005; Munshi et al., 2006; Singh, Govil, Kumar, & Kumar, 2017). Promoting and maintaining cognitive health has become a higher priority in low-and-middle income countries where populations are increasingly aging, and India is no exception to this trend (Kalaria et al., 2008). It is therefore important to examine the determinants of late-life cognitive health in the context of India's country-specific socioeconomic, demographic and regional diversities. This is a precondition for designing an effective public health policy aiming to improve cognition among older Indian men and women, and to ensure healthy lives for all in general.

Gender difference in cognitive ability has been widely studied in developed countries, as compared to developing countries (Kalaria et al., 2008). A common finding from studies conducted in the United States and in European countries is that cognitive health among women is as good as among their male counterparts or better (De Frias, Nilsson, & Herlitz, 2006; Langa et al., 2009; Lewin, Wolgers, & Herlitz, 2001; Weber, Skirbekk, Freund, & Herlitz, 2014). By contrast, studies in low- and middle-income countries including India (Oksuzyan, Singh, Christensen, & Jasilionis, 2017), Burkina Faso (Onadja, Atchessi, Soura, Rossier, & Zunzunegui, 2013) and countries in Latin America (Nguyen, Couture, Alvarado, & Zunzunegui, 2008) have indicated lower cognitive performance among women than among men.

In India, there have been few studies on gender difference in cognitive health among older adults, and these report mixed results. For instance, a study conducted in the Indian state of Himachal Pradesh did not find any difference between men and women in Mini Mental State Exam (MMSE) scores (Sharma, Mazta, & Parashar, 2013). Similarly, no female disadvantage in MMSE scores among older persons aged 55–84 years was indicated in south India (Mathuranath et al., 2003).

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However, in the northern state of Haryana women did worse than men on the MMSE test (Ganguli et al., 1995). Recently, three large-scale population-based studies have shown that men perform much better than women in cognitive health, even after adjusting for various socioeconomic, demographic and health behavior characteristics (Lee, Shih, Feeney, & Langa, 2014; Oksuzyan et al., 2017; Weir, Lay, & Langa, 2014). The limited numbers of studies that have examined the determinants of gender difference in cognitive health in India have mainly discussed individual level characteristics. For instance, age, education, height, chronic health status and marital status have been shown to be prominent factors modifying the gender gap in cognitive health among older adults in India (Lee et al., 2014; Oksuzyan et al., 2017). However, no studies have examined the relationship between cognitive health and state-specific characteristics. Previous studies in India have shown significant associations between contextual level factors (such as healthcare spending, poverty, immunization coverage and women's education) and mortality among children (Dwivedi, Begum, Dwivedi, & Pandey, 2013; Van der Klaauw & Wang, 2004) and young adults (Farahani, Subramanian, & Canning, 2010), but have not found any association between state-level public health spending and morbidity (Farahani et al., 2010). A recent population-based study in India observed significant neighborhood-level differences in health among older adults, but did not include any specific neighborhood characteristics in the analysis (Ghosh, Millett, Subramanian, & Pramanik, 2017).

Previous studies in India have shown that there are remarkable regional disparities in socioeconomic and health indicators (Nayyar 2008; Subramanian *et al.* 2006) and in gender discrimination (Sen & Östlin, 2008). States such as Karnataka and Maharashtra perform relatively well in many socioeconomic and demographic parameters compared with states such as Rajasthan and Uttar Pradesh. For instance, female literacy was over 75 percent in Maharashtra but the corresponding figure in Rajasthan was 52 percent, according to the 2011 Census. Similarly, female labor force participation during 2013-14 varied from around 35 percent in Maharashtra and Karnataka to 15 percent in Uttar Pradesh (GoI, 2014). Earlier studies have shown that there is better implementation of key healthcare interventions such as antenatal care, institutional delivery and child vaccination in southern Indian states as compared to the northern and the eastern Indian states (Kumar, Singh, & Rai, 2013; Singh, 2013). Similarly, during 2010-14 the gap in life expectancy at birth between Assam (63.9) and Maharashtra (71.6) was 7.7 years. According to the Census 2011, many north Indian states recorded a child sex ratio below 850 (number of girls for every 1000 boys in the 0–6 age range), while the child sex ratio was over 950 in several south Indian states (Jha et al., 2011). The regional dimension is also likely to play a key role in explaining the gender gap in cognitive health, because in India's federal structure state governments play a larger role than the central government in health service provision (Balarajan, Selvaraj, & Subramanian, 2011b; Joshi, 2006). For instance, per capita public health expenditure was considerably lower in states like Uttar Pradesh (Indian National Rupees (INR) 128), Assam (INR 162) and Rajasthan (INR 186) as compared with Karnataka (INR 233) (MoHFW, 2009).

The share of those aged 60+ in the overall population of India will reach 19 percent by 2050, an increase of approximately 222 million aging persons (UN, 2013). The higher level of cognitive impairment among older women in India than among their male counterparts, coupled with persisting gender norms, poses a significant challenge to the country. In our study, we examined the gender differences in cognitive health across six selected states of India: Assam, Karnataka, Maharashtra, Rajasthan, Uttar Pradesh, and West Bengal. As per the WHO-SAGE India report, these states were selected based on the systematic random sample selection process while taking into account four important indicators of development within each state: infant mortality rate, female literacy rate, percentage of safe deliveries (births) and per capita income (Arokiasamy, Parasuraman, Sekher, & Lhungdim, 2013). Using multilevel modelling, the study examined whether and to what extent state level characteristics such as female education, urbanization, female workforce participation, social group composition and under-five mortality affect the gender difference in cognitive health among older Indian adults, after controlling for demographic, socioeconomic and health behavior determinants observed at the individual level.

2. Design and methods

2.1. Study population

Our study used data from Wave 1 of the WHO-Study of Global AGEing and Adult Health (SAGE), which was conducted in 2007-08 as part of a multi-country survey to assess the health and well-being of the adult population in six selected countries – China, Ghana, India, Mexico, the Russian Federation and South Africa (Kowal et al., 2012). In India, the survey was implemented in six selected states – Assam, Karnataka, Maharashtra, Rajasthan, Uttar Pradesh and West Bengal. These six states accounted for 37 percent of India's population and represented diversity in various socio-cultural, geographical and demographic dimensions (Supplementary Table 1). A multistage, stratified clustered sample design was used to generate random samples from both urban and rural areas. Allocation of households across six states was done according to their population size. The overall individual response rate was 92 percent, with state level variations from highest in Assam (95 percent) to lowest in Karnataka (89 percent). The analytical sample size for this study was based on 6548 individuals who were aged 50 or older at the time of survey and did not have obvious cognitive limitations. To assess whether respondents aged 50-plus were cognitively capable of understanding and completing the survey, a short set of questions about memory was inserted in the individual schedule before the main set of questions. These preliminary questions helped the interviewer to subjectively determine whether respondents were cognitively competent to complete the interview. However, in the Indian sample no participant was excluded from performing the cognitive tests based on the interviewer's assessment of cognitive limitations. More details related to the inclusion and exclusion criteria of individuals can be found in the WHO-SAGE India report (Arokiasamy et al., 2013).

2.2. Outcome variable

The survey included tests of verbal fluency and verbal recall, as well as a forward and backward digit test to measure the cognitive health of older adults (Supplementary Table 2). The older adults were asked to recall, immediately and after a delay of around ten minutes, as many nouns as they could out of 12 listed. During forward and backward digit span tests the interviewers read a series of digits and asked participants to repeat them immediately. In the backward test, the participants had to repeat the numbers in reverse order. The verbal fluency of survey participants was examined based on the number of animals named in one minute. As a first step, z-scores were generated to standardize the values for each test separately. An overall composite cognitive score (CCS) was then calculated by summing the z-score of five individual cognitive tests (Christensen et al., 2013).

2.3. Covariates

The analysis included various socioeconomic, demographic, health behavior and region-specific variables as potential confounders. The main variable of interest for our study was the gender of the respondents. Age was grouped into six categories (50–54, 55–59, 60–64, 65–69, 70–79, 80+) and marital status as non-married (never married/divorced/separated) and currently married. Height of the respondents was included in our study as the proxy indicator of early childhood conditions, namely nutritional status and burden of infectious diseases

Table 1
State-wise sample distribution in WHO SAGE India, 2007–08.

Background variables (%)	**Assam** (North-east)		**Karnataka** (South)		**Maharashtra** (West)		**Rajasthan** (North)		**Uttar Pradesh** (Central)		**West Bengal** (East)	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Age												
50–54	24.6	26.9	16.4	20.9	21.7	24.8	23.6	23.5	19.3	24.3	25.1	29.1
55–59	19.1	25.4	18.7	23.3	21.7	22.7	19.4	18.4	22.9	24.0	19.0	21.4
60–64	14.7	19.9	19.5	18.4	16.7	18.5	18.5	20.2	19.6	19.2	18.8	14.8
65–69	19.6	12.7	18.9	14.3	18.3	16.5	16.8	16.8	16.2	11.2	15.5	15.9
70–74	9.6	8.2	12.7	11.7	12.6	8.9	11.0	10.6	13.0	10.1	9.7	10.6
75–79	6.2	4.2	6.4	5.0	5.7	5.7	5.7	4.4	4.6	4.6	6.6	3.7
80+	6.2	2.7	7.6	6.4	3.3	3.1	5.1	6.2	4.4	6.6	5.2	4.7
Current marital status												
Non-married	14.7	50.5	10.0	42.6	8.9	39.5	12.3	37.4	18.0	29.2	8.8	45.6
Married	85.3	49.6	90.0	57.4	91.1	60.5	87.7	62.6	82.0	70.8	91.2	54.4
Education												
Never attended	44.6	72.2	57.5	80.4	35.0	68.2	61.0	92.2	47.1	84.5	33.5	70.2
Primary	20.7	10.7	9.6	9.3	24.3	17.1	12.9	5.3	12.2	7.1	26.8	16.3
Secondary & above	34.8	17.2	32.9	10.3	40.7	14.7	26.1	2.6	40.7	8.4	39.7	13.5
Tobacco consumption												
Never used	24.7	43.7	33.4	65.9	37.1	74.2	28.8	83.0	20.6	61.5	21.7	64.7
Former user	8.4	1.3	11.5	2.8	7.1	1.1	7.8	1.1	5.4	3.5	12.2	1.7
Current user	66.9	55.0	55.1	31.4	55.8	24.7	63.4	15.9	74.0	35.0	66.0	33.6
Chronic health condition												
None	51.9	49.8	27.7	34.5	46.8	45.3	62.9	66.3	56.2	50.5	47.9	42.0
1	33.2	30.7	27.2	30.4	28.9	28.6	24.1	23.8	27.3	31.9	29.5	32.7
2+	15.0	19.4	45.1	35.1	24.3	26.2	13.0	9.8	16.5	17.6	22.6	25.3
Social groups												
General/OBCs	64.1	68.1	84.0	83.1	85.5	86.0	76.9	76.7	78.5	81.3	68.0	69.6
SCs/STs	35.9	31.9	16.0	16.9	14.5	14.0	23.1	23.3	21.5	18.8	32.0	30.5
Religion												
Hindu	75.8	73.8	91.4	91.1	88.3	87.1	85.2	87.3	82.8	83.7	80.5	79.8
Others	24.2	26.2	8.6	8.9	11.7	12.9	14.8	12.7	17.2	16.3	19.5	20.2
Place of residence												
Urban	15.0	24.8	32.0	33.0	40.8	43.0	18.5	18.9	14.3	17.0	27.9	30.3
Rural	85.0	75.2	68.0	67.0	59.2	57.0	81.6	81.1	85.7	83.0	72.1	69.7
Sample (gender-specific)	**387**	**331**	**488**	**545**	**628**	**618**	**721**	**746**	**755**	**671**	**637**	**623**
Total sample	**718**		**1033**		**1246**		**1467**		**1426**		**1260**	

(Guven & Lee, 2013; Steckel, 2009). The education of the respondents was coded as: never attended school, primary completed and secondary or higher. Tobacco use included smoking, sniff, and chew, and respondents categorised as: never, former, and current user. Chronic morbidity was identified based on eight self-reported physician-diagnosed chronic conditions - angina, arthritis, asthma, stroke, diabetes, depression, chronic lung disease, and hypertension. Respondents were categorized as having no, one and two or more chronic illnesses. The composition of the Indian population is significantly influenced by religious affiliation and social identity (Castes). Previous studies in India have documented poorer health and lower socioeconomic status among certain religious (Muslim) and caste (Scheduled Caste and Scheduled Tribes) groups as compared with Hindus and higher castes respectively (Desai & Kulkarni, 2008; Nayar, 2007). Religious affiliation was divided into two groups – Hindus vs. all others. The identification of caste group was based on the respondent's self-report and was grouped into General/Other Backward Categories and Scheduled Castes/Scheduled Tribes.

To capture regional heterogeneity in key socioeconomic, demographic and developmental dimensions, the study used various state-specific indicators including urbanization, female literacy, female workforce participation, proportions of Scheduled Castes (SC) and Scheduled Tribe (ST) populations and under-five mortality rate. Environmental deprivation, including rural life and poverty and illiteracy during childhood and adulthood, is significantly associated with poor cognitive function in old age (Turrell et al., 2002). As the sampling frame of SAGE Wave 1 survey was based on Census 2001 figures, we derived state-specific figures for urbanization, SC/ST and female literacy for the same year. State-wise female workforce participation was obtained from the National Family Health Survey conducted in 2005-06 (International Institute for Population Sciences and Macro International, 2007). The analysis considered the state-specific under-five mortality (per 1000 live births) for 1971, drawn from the Sample Registration System, because this represents the overall state of healthcare and mortality for the period when the current older population were in their early childhood (Office of the Registrar General & Census Commissioner, 2011a).

2.4. Analytical strategy

We first examined the gender difference in the age-standardized mean scores for cognitive function across the six selected states of India. The multilevel analysis was used to segregate cognitive health between states and for selected socioeconomic and demographic characteristics at the individual level. The SAGE Wave 1 sampling design allowed us to apply multilevel modeling, as it follows the hierarchical structure of data – individuals are nested within primary sampling units (PSU) and PSUs are nested within urban and rural stratum in each state. We fitted multilevel ordinarily least squares (OLS) regression models with a random intercept attributable to clustering within six states further divided into urban and rural parts (12 geographic units). The multilevel analysis was applied in order: (A) to examine the inter-state variance in terms of the set of control variables and (B) to investigate the extent of individual–and–state level characteristics modifying gender gaps in

CCS.

The following models were estimated:

Model 1: Empty model
Model 2: Gender and age
Model 3: Model 2+ education
Model 4: Model 3 + all individual variables
Models 5.1–5.5: Model 2+ state level characteristics (one for each characteristic)
Models 6.1–6.5: Model 3 + state level characteristics (one for each characteristic)
Models 7.1–7.5: Model 4 + state level characteristics (one for each characteristic)

The variance parameter σ_B^2 quantifies heterogeneity between states, after taking into account covariates in the fixed part. The analysis was performed using Stata version 12 (StataCorp, 2011).

3. Results

3.1. Descriptive statistics

Table 1 presents the description of the sample population across the six selected Indian states. In all states, the proportion of non-married was considerably higher among women than among men. For instance, in Maharashtra, where the difference was the highest, only 9 percent of the men were non-married, compared with 40 percent of the women. Over 70 percent of the women in all the states had no formal schooling, which was much higher than for their male counterparts. Illiteracy among women was highest in Rajasthan (92 percent) and lowest in Maharashtra (62 percent). On the other hand, the highest proportion of women who completed secondary level of schooling and above (17 percent) was in Assam, and the lowest in Rajasthan (3 percent). The proportion of men and women suffering from two or more chronic illnesses was highest in Karnataka and lowest in Rajasthan. The sample of men and women belonging to the SC/ST social group was highest in Assam, followed by West Bengal and Rajasthan. A majority of the older adults were living in rural areas across all selected states. The age-standardized mean CCS shows a considerable gender gap across all six selected states (Table 2). For instance, the mean CCS was 0.73 (*SE* = 0.15) for men and -0.50 (*SE* = 0.13) for women in Karnataka. Similarly, in the case of Rajasthan, the men's mean CCS was 1.28 (*SE* = 0.13), whereas for women it was considerably lower at -1.21 (*SE* = 0.11).

Table 2
Age-standardized mean cognitive score across selected states of India, WHO-SAGE 2007–8.

Selected states		Mean	SE	Sample	*p*-value of gender difference (t-test)
Karnataka (South)	Men	0.73	0.15	419	< 0.001
	Women	-0.50	0.13	504	
Assam (Northeast)	Men	0.18	0.17	367	< 0.001
	Women	-1.91	0.18	308	
Maharashtra (West)	Men	1.54	0.13	546	< 0.001
	Women	-0.07	0.14	549	
Rajasthan (North)	Men	1.28	0.12	676	< 0.001
	Women	-1.21	0.11	701	
Uttar Pradesh (Central)	Men	1.05	0.11	703	< 0.001
	Women	-1.26	0.12	605	
West Bengal (East)	Men	0.54	0.15	586	< 0.001
	Women	-1.13	0.15	584	

3.2. Multilevel results

The multilevel analysis suggests that the intercept-only model yields variance estimates of 7.43 (*SE* = 1.04) for mean CCS across 12 geographic units (Table 3). Twelve percent of the variation in CCS lies between the states (or geographical areas) and the other 88 percent lies between individuals within states. The corresponding geographical-level contribution to the total variances was 12 percent, indicating spatial variations in CCS. As expected, controlling for age *(Model 1)* leads to substantial declines in both the variance and the geographic-level contribution to the variance. Another important (about 50 percent) decrease can be observed after controlling for the remaining individual characteristics (Table 4). At the same time, no further decline in between-state variance was evident after the selected or even all the state-level characteristics were included in the model. These results suggest that the effects of state-level factors on mean CCS are very low, and that controlling for geographical characteristics does not modify the male-female gap in mean CCS. The findings suggest that age, education, marital status, height, suffering from two or more chronic illnesses and belonging to the SC/ST social groups are the key variables that significantly determine the mean CCS among older Indian adults.

Table 3 provides insights into how controlling for different individual and state-level variables modifies the gender differential in cognitive health. *Model 2* controlling for age and gender, shows a significant negative coefficient for women, indicating that women perform worse than men in CCS (β = -1.99, 95% CI: -2.14, -1.84). Introducing education in *Model 3* substantially reduces the gender gap in cognitive function (β = -0.97, 95% CI: -1.12, -0.82). In *Model 4*, we control for marital status, height, tobacco consumption, chronic health condition, religion and caste, and the gender gap declines further (β = -0.50, 95% CI: -0.71, -0.29), but remains statistically significant. In the next *Models* (5.1–7.5), which were additionally controlled for state-level characteristics, we find that none of the state-level characteristics (in addition to the individual-level variables) reduces the gender gap in CCS significantly (Table 4 **and** Supplementary Tables 3–5). However, the results reveal that state level urbanization (β = 0.03, 95% CI: -0.04, 0.59) and female workforce participation (β = 0.04, 95% CI: 0.01, 0.07) are positively associated with the CCS (*Model 7.2 & 7.3;* Supplementary Table 5).

4. Discussion and conclusion

We set out to investigate whether and to what extent selected state-level characteristics such as female literacy, female labor force participation, urbanization, under-five mortality and proportion of SC/ST population modify the gender difference in cognitive health among older Indian adults after controlling for other individual level variables. The study found a very pronounced gender difference in cognitive health among older adults in India, which persisted after adjusting for selected individual-level socio-demographic and health behavior variables and selected characteristics at the state level. The finding is consistent with those of other studies conducted in India (Lee et al., 2014; Oksuzyan et al., 2017; Onur & Velamuri, 2016) and other low-and-middle income countries (Lyu & Kim, 2016; Sternäng, Lövdén, Kabir, Hamadani, & Wahlin, 2016; Yount, 2008), which have reported worse cognitive health among women as compared to men. Our analyses show that individual level variables substantially reduce the gender gap in cognitive health. State-level characteristics, however, do little to explain the female disadvantage in cognition among older Indian adults. This finding is unexpected, considering the substantial variations in cognitive health and its determinants across the selected states and their urban and rural sub-populations.

The male-female difference in CCS declined substantially once we controlled for education in the analysis. Further declines in gender difference in cognitive health were observed after adjusting for marital status, caste, religion, tobacco consumption, height, and chronic health

Table 3
Multilevel analysis of gender difference in poor cognitive health among older adults, India.

Background variables	**Model 1** (Null model)			**Model 2**			**Model 3**			**Model 4**		
	Coef.	95%CI	p-value	Coef.	95%CI	p-value	Coef.	95%CI	p-value	Coef.	95%CI	p-value
Fixed effect												
Gender												
Men (ref.)												
Women				-1.99	(-2.13; -1.84)	< .001	-0.97	(-1.12; -0.82)	< .001	-0.50	(-0.71; -0.29)	< .001
Age												
50–54 (ref.)												
55–59				-0.31	(-0.54; -0.09)	.006	-0.28	(-0.49; -0.07)		-0.27	(-0.48; 0.07)	
60–64				-0.94	(-1.18; -0.71)	< .001	-0.64	(-0.86; -0.42)	< .001	-0.55	(-0.76; -0.33)	< .001
65–69				-1.21	(-1.46; -0.97)	< .001	-0.81	(-1.04; -0.59)	< .001	-0.61	(-0.83; -0.38)	< .001
70–74				-1.76	(-2.04; -1.49)	< .001	-1.32	(-1.58; -1.06)	< .001	-1.08	(-1.34; -0.82)	< .001
75–79				-2.13	(-2.50; -1.77)	< .001	-1.53	(-1.86; -1.19)	< .001	-1.31	(-1.65; -0.96)	< .001
80+				-3.19	(-3.56; -2.82)	< .001	-2.44	(-2.78; -2.10)	< .001	-1.86	(-2.23; -1.49)	< .001
Education												
Never attended (ref.)												
Primary							1.76	1.54	< .001	1.64	(1.43; 1.85)	< .001
Secondary & above							3.29	3.10	< .001	3.09	(2.90; 3.28)	< .001
Current marital status												
Non-married (ref.)												
Married										0.51	(0.33; 0.68)	< .001
Height										0.03	(0.02; 0.04)	< .001
Tobacco consumption												
Never used (ref.)												
Former user										-0.26	(-0.59; 0.06)	.114
Current user										-0.18	(-0.33; -0.02)	.027
Chronic health condition												
None (ref.)												
1										-0.08	(-0.25; 0.08)	.306
2+										-0.33	(-0.51; -0.14)	< .001
Social group (Caste)												
General/OBCs (ref.)												
SCs/STs										-0.43	(-0.61; -0.26)	< .001
Religion												
Hindu (ref.)												
Others										-0.04	(-0.23; 0.16)	.722
Random effect												
Var_cons (SE)	1.03	(1.04)		0.81	(0.32)		0.33	(0.143)		0.28	(0.122)	
Var_residual (SE)	7.43	(0.81)		8.89	(0.17)		8.11	(0.141)		7.38	(0.132)	
Intra-class correlation (ICC) in %	12.2			8.4			3.9			3.7		
Number of obs.	6496			6496			6496			6496		
Number of groups	12			12			12			12		

CI = Confidence interval

status. Empirical evidence from both developed and developing countries has highlighted several pathways through which education is related to cognitive function. Better schooling in the early years promotes the development of brain reserve capacity through increase in both overall and regional brain sizes (Schmand, Smit, Geerlings, & Lindeboom, 1997). It is also related to economic activities that require greater mental stimulation (Nguyen et al., 2008) and perhaps higher contact with social networks having similar or higher levels of formal schooling (Cagney & Lauderdale, 2002). Formal schooling has been shown to play a role in increasing productivity in non-market outcomes including consumption, savings, own health, fertility and child health and cognitive development (Grossman, 2005).

In the Indian context, lack of formal schooling may affect women disproportionately. According to Census 2011, despite the different educational polices implemented since independence (Kingdon, 2007), the gap between men and women in schooling was over 15 percent (I. Office of the Registrar General & Census Commissioner, 2011b). The gender gap in educational outcomes is largely driven by community and family attitudes towards girls' education in the south Asian context (Sonalde *et al.* 2010). For instance, studies have shown that the importance of the social and religious roles attributed to sons in the Indian kinship system, the huge financial burden at the time of a girl's marriage, and the perception that the returns to a daughter's education mainly benefit her in-laws' family are among the prominent factors affecting the allocation of higher levels of emotional and financial resources to sons at the expense of daughters (Chudgar, Shafiq, & Kingdon, 2005; Chudgar & Shafiq, 2010). Also, as suggested previously, the cohort of women analyzed in the present study may have experienced even worse forms of discrimination during their early childhood and adulthood, as they were born and brought up in an environment of even greater cultural rigidity than under present day conditions (Oksuzyan et al., 2017).

Table 4
Multilevel analysis of gender difference in poor cognitive health among older adults, India.

	Coef.	P > t	95%CI			Coef.	P > t	95%CI			Coef.	P > t	95%CI	
Reference – Male					Reference – Male					Reference – Male				
Model 5.1	-1.99	< .001	-2.14	-1.84	**Model 6.1**	-0.97	< .001	-1.12	-0.82	**Model 7.1**	-0.50	< .001	-0.71	-0.29
Model 5.2	-1.99	< .001	-2.14	-1.84	**Model 6.2**	-0.97	< .001	-1.12	-0.82	**Model 7.2**	-0.49	< .001	-0.70	-0.28
Model 5.3	-1.99	< .001	-2.14	-1.84	**Model 6.3**	-0.97	< .001	-1.12	-0.82	**Model 7.3**	-0.49	< .001	-0.70	-0.28
Model 5.4	-1.99	< .001	-2.14	-1.84	**Model 6.4**	-0.97	< .001	-1.12	-0.82	**Model 7.4**	-0.50	< .001	-0.71	-0.29
Model 5.5	-1.99	< .001	-2.14	-1.84	**Model 6.5**	-0.97	< .001	-1.12	-0.82	**Model 7.5**	-0.50	< .001	-0.71	-0.29

CI = Confidence interval;
Models 5.1–5.5: gender, age + state level female literacy, urbanization, female workforce participation, proportion of SC/ST population, under-five mortality rate (one for each model);
Models 6.1–6.5: gender, age, education + state level female literacy, urbanization, female workforce participation, proportion of SC/ST population, under-five mortality rate (one for each model);
Models 7.1–7.5: all individual level + state level female literacy, urbanization, female workforce participation, proportion of SC/ST population, under-five mortality rate (one for each model)

Our study found that poor cognitive health was significantly more prevalent among those who were non-married (mainly the 24% who were widowed) compared to married older adults. This finding may be driven by several factors. Firstly, persons with higher cognition and intelligence scores are more likely to marry and stay in union (Aspara, Wittkowski, & Luo, 2018). Secondly, married individuals engage more in social and cognitive activities than those who are non-married (Feng et al., 2014). Thirdly, as compared with their married counterparts, single individuals may experience more psychological stress and loneliness, which are associated with a higher risk of cognitive impairment (Feng et al., 2014; Johansson et al., 2010). In Indian culture, widowed women are often not allowed to participate in family or community activities and are confined to a very limited physical and social space by their parents-in-law (Chen & Drèze, 1992), which may restrict or damage their cognitive ability.

Our findings support previous evidence of a positive association between height and cognitive health among older adults in India (Oksuzyan et al., 2017). There is compelling evidence that height is a proxy for early childhood nutrition and environment, which affects economic outcome and cognition throughout life (Case & Paxson, 2008; Guven & Lee, 2013). Girls in India are more under-nourished (Pande, 2003; Raj, McDougal, & Silverman, 2015), and receive fewer vaccinations (Singh & Parasuraman, 2014) than boys in the early childhood years. Moreover, the higher prevalence of anemia and underweight among Indian women is the highest among all countries (Balarajan, Ramakrishnan, Özaltin, Shankar, & Subramanian, 2011a), reflecting their social vulnerability in the community (Bloom, Wypij, & Gupta, 2001).

Poor cognitive health among older adults belonging to the lower castes (SCs and STs) is evident in this study. In Indian society, caste has been considered a proxy for socioeconomic status and poverty (Thorat & Neuman, 2012). Certain caste groups (mainly SCs and STs) have lived under adverse conditions for centuries, and still have limited access to basic facilities, including safe drinking water, improved sanitation (Deshpande, 2000) and food from the public distribution system (Thorat & Lee, 2010), and have greater mortality risks across the life course as compared to the higher castes (Subramanian et al., 2006). While it is true that certain caste groups as a whole are oppressed, women bear a disproportionately higher share of this burden. One study has estimated that life expectancy among women belonging to the SCs is considerably lower than that of women from a relatively higher caste group, mainly due to higher exposure to mortality-inducing factors such as bad sanitation, poor housing conditions, and unsafe water supply (Barooah, Sabharwal, & Thorat, 2012). Similarly, access to education, nutrition and healthcare among SCs and STs women has been found to be substantially lower than among higher caste women (Desai & Kulkarni, 2008; Singh, Rai, Alagarajan, & Singh, 2012). Under such circumstances, there is a strong likelihood of poor cognitive health among SCs and STs as compared to other social groups.

Our results show the largest gender gap in CCS in Rajasthan and the lowest in Karnataka (Table 2), which is similar to previous reports of variations in gender difference in health across Indian states. Lee et al. found a higher gender disparity in cognitive functioning in Punjab and Rajasthan (north) as compared to Kerala and Karnataka (south). However, the reasons which account for higher female disadvantage in the north than in the south remain unclear (Lee et al., 2014). Our analyses further show that state level urbanization (model 7.2; Supplementary Table 5) and female workforce participation (model 7.3; Supplementary Table 5) play a role in determining cognitive health, although their contribution is very small. However, these characteristics do not explain gender difference in cognition among older Indian adults. One possible reason for this may be that the cohort of older women analyzed in this study were largely deprived of education and other opportunities, irrespective of state of residence. As a result, it is the individual-level variables that show strong effects on the gender gap in cognitive health in this study, rather than the state-level characteristics. Recent estimates suggest that India remains a country where women's economic participation and opportunities are among the lowest in the world (Word Economic Forum 2017). Women are often pushed by family members to take up non-wage employment or to remain out of the labour force (Kapsos, Silbermann, & Bourmpoula, 2014; Srivastava & Srivastava, 2010). Earlier studies have highlighted that lower occupational attainment and poor quality of work are strongly associated with a higher risk of cognitive impairment (Evans et al., 1997; Park et al., 2005). The positive link between urbanization and cognitive health among older adults in this analysis may be related to the relatively higher proportion of older adults receiving pension benefits, health insurance, and social support and having better access to healthcare facilities in urban areas as compared to their counterparts residing in rural areas (Roy & Chaudhuri, 2008; Xu, Dupre, Gu, & Wu, 2017). States with higher levels of urbanization offer more educational and occupational opportunities for women throughout the life span, as compared to women residing in rural areas (Raina *et al.* 2014).

The study provides important insights for policy implications in India. To potentially reduce gender gaps in cognitive health, policy makers could invest resources to ensure equal educational opportunities for Indian women and men at younger ages and to implement more effective laws, which aim at minimizing gender inequalities in wages and pensions at working and older ages. To ensure adequate financial security and independence of older women, regardless of their marital status, policy makers in India could also work toward improving legal mechanisms which ensure and strengthen women's property and inheritance rights. Finally, cognitive health of women may be strengthened by supporting social networks which show protective effects against depression among older people in India (Singh, Singh, & Arokiasamy, 2016).

There are a few limitations of this study that need to be mentioned. The cross-sectional design limits our ability to establish causality. As the survey was conducted in 2007-08, the results of this study may not reflect the current level of cognitive health in the Indian population. However, the WHO SAGE is the most recent and exclusive survey covering cognitive health among older adults in India. Considering the huge diversity across Indian states, six states may not be sufficient to represent all the cultural, socioeconomic and demographic variations, but no such large survey in India covers cognitive health dimensions for older adults. Because we had very few states in the analysis, we were inevitably limited to examining regional variations in gender differences in cognition among adults. Other state-level characteristics such as spending on healthcare, or education or poverty status, may be more important in explaining regional and gender disparity in cognitive health and should be considered in future analyses when data becomes available. The present study was unable to include characteristics reflecting the early- life and childhood (e.g. food deprivation) and adulthood (e.g. social network) experiences of older adults when analyzing the gender gap in cognitive health, because this information was not included in the WHO SAGE data collection instrument.

To conclude, this article helps to advance our understanding of female disadvantage in cognitive health among older adults in India, taking into consideration both individual and state-level contextual variables. Our study demonstrates that individual level characteristics are the important determinants of gender difference in cognitive health among older adults. Women's education emerges as the key factor that substantially modifies gender difference in cognitive function, followed by height, marital status, chronic health condition and caste. We also show a significant association between selected region-specific characteristics, particularly urbanization and female labor force participation, with cognitive health among older adults in India. More research is needed to examine causal pathways through which discrimination against Indian women throughout the life course affects their cognitive health.

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Declarations of interest

None

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Ethical statement

The present study is based on the WHO-SAGE data available in the public domain for researchers to use with all identifying information removed. Thus, no ethical clearance is required for this study.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ssmph.2018.06.008.

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