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Prevalence of left-handedness in China 2011: Small-area estimates

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ABSTRACT

Nationally representative survey data and small-area estimation techniques are used to assess the geographic prevalence of left-handedness in China 2011. Measures of individuals' handedness are their self-reported dominant hand and their hand grip strength, which yield four estimates of left-handed prevalence, and these statistics are recorded at the provincial level. These estimates concord with one another. There are several geographic clusters of high-prevalence rates of left-handers located in ethnic minority-designated autonomous areas or historically revolutionary base areas, which may reflect a deep-rooted sense of defiance to authorities and promote such cultural values as individual autonomy and equality among local people.

KEYWORDS

Grip strength; left-handedness; small-area estimation; spatial analysis

1. Introduction

About 10% of the world population are left-handed (McManus, 2009). Prevalence rates of left-handed people may vary across space and generations. Johnston et al. (2013) found that in USA, left-handed children performed worse in cognitive tests than right-handed children. In contrast, in samples of British children from six primary schools, Annett (1993) found a negative association between right-handedness and a cognitive test score. Bryden et al. (2005) found that left-handed Canadian college students were more likely to report various health disorders than their right-handed peers. Denny (2009) also found that left-handed European older adults were more likely to experience depressive symptoms than their right-handed peers, but Denny and O'Sullivan (2007) found that left-handed men earned more.

Brackenridge (1981) surveyed children from seven private Melbourne schools and their family members and reported that left-handed prevalence rate had increased from 2% to 13% over the period 1880–1969 in Australia. Pooling data from 81 samples studied between 1922 and 1998, Raymond and Pontier (2004) reported that prevalence rates of left-handed throwers

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or hammerers ranged from 4.4% among Japanese men to 27.9% among French women. In his review, McManus (2009) concluded that in Europe, left-handed prevalence rates were higher in the UK, Holland, and Belgium than in eastern and southern European countries, and that in the UK, the left-handed rate was lower among immigrants than among natives. They studied specific groups, such as clinical patients, college students, and magazine subscribers (Gilbert and Wysocki, 1992), who were not representative of the population. Porac and Coren (1981) even studied left-handedness of the people depicted in artworks. The 1986 Smell Survey, conducted by Wysocki and Gilbert (1989) at the *National Geographic* magazine, comprised 1.42 million respondents world-wide, among whom 1.2 million lived in the USA. Based on this survey, McManus (2009) computed the prevalence of left-handedness at the US state level. However, the response rate was only 13.5% and the respondents were mostly college-educated, wealthy whites, and not representative of the US population.

The British Broadcasting Corporation (BBC) Internet Survey conducted in 2005 comprised a question about hand preference for writing, to which 255,110 participants responded (Peters et al., 2006). Fifteen countries counting more than 1,000 participants (Reimers, 2007) were represented, allowing international comparison (McManus, 2009). The response rate was only 50%, and the respondents were not representative of their respective countries (Peters et al., 2006; Reimers, 2007).

Denny and O'Sullivan (2007), based on the longitudinal British 1958 National Child Development Survey, a longitudinal study of all persons living in Great Britain born between March 3 and 9, 1958, found that left-handedness had a positive effect on men's earnings but a negative effect on women's earnings. Johnston et al. (2009), based on the first wave of the Longitudinal Study of Australian Children conducted in 2004, found that left-handed children performed worse in cognitive measures and social-emotional development measures. Ruebeck et al. (2007), based on the National Longitudinal Survey of Youth, found a positive wage effect of left-handedness among men but not among women.

Here, I estimate the geographic variation in left-handed prevalence from the nationally representative China Health and Retirement Longitudinal Study. I use small-area estimation to estimate left-handed prevalence and grip strength at the provincial level. Grip strength is a biomarker of aging. On the basis of the measure of grip strength, I find that the prevalence of left-handedness exceeds 20%, while it is below 15% when measured by self-reported dominant hand. Model-based small-area estimates have smaller variances than design-based estimates. I also find three spatial clusters of higher left-handed prevalence rates in areas populated by minorities and areas with a revolutionary history.

2. Data

The China Health and Retirement Longitudinal Study is a biennial survey of a nationally representative sample of Chinese residents aged 45 and older, and their spouses if any. The national baseline of China Health and Retirement Longitudinal Study, completed in 2011, comprises 10,287 households and 17,708 individuals living in 150 counties across 28 out of 31 provinces in mainland China, with a response rate of 80.5% (Zhao et al., 2014).

The measure of individual-level handedness is based on the question: “Which is your dominant hand?” (choices: right hand, left hand, or both hands equally dominant). I used a dichotomous variable coded 1 for left-handed and 0 for right-handed or ambidextrous. Left-handed people may lie when left-handedness is considered as an abnormality. In the China Health and Retirement Longitudinal Study, hand grip strength is measured with a hand-held dynamometer (Zhao et al., 2013a). The retained grip strength for each hand is the maximum value of two measurements (Roberts et al., 2011). I classified each respondent as left-handed if his or her grip strength was greater with the left than with the right hand. I also classified each respondent as left-handed if his or her grip strength was greater of at least one pound (= 0.45 kilogram) with the left than with the right hand (Siengthai et al., 2008). The spatial patterns of left-handed prevalence rates were similar when using these two grip strength measures.

To apply the post-stratification weights taken from China’s 2010 population census, I coded a set of individual-level covariates in China Health and Retirement Longitudinal Study into the same categories as the cross-tabulated census statistics at the provincial level. These individual covariates include quinquennial age in 2010 (from 45–49 to 80–84, and over 85), sex, educational attainment, and rural or urban residence.

3. Method

Direct estimates of left-handedness prevalence from the China Health and Retirement Longitudinal Study are not reliable for small areas, because data are either unavailable or convene too small sample sizes. The overall survey is nationally representative, but not of each province. That is why I employed the multilevel regression with post-stratification weighting (Gelman and Little, 1997; Park et al., 2004; Zhang et al., 2014). First, I estimate a multilevel logistic model for individual-level left-handedness, using individual demographic and socioeconomic characteristics and provincial random intercepts as predictors:

$$\text{logit}(P_{ijkp}(y_{ijkp} = 1)) = \sum_{45-49}^{85+} \alpha_i \text{age}_i + \beta_j \text{sex}_j + \sum_{\text{none}}^{\text{college}+} \gamma_k \text{education}_k \quad (1) \\ + \delta_r \text{residence}_r + \nu_p,$$

where in province p , y_{ijkp} is a dichotomous indicator of left-handedness (1 = left-handed; 0 = right-handed or ambidextrous) for an individual of age group i ($i = 45-49, 50-54, \dots, 80-84$, and 85 or older), sex j (1 = men; 0 = women), educational attainment k (1 = none, 2 = primary school, 3 = middle school, 4 = high school, and 5 = college or above), and residence r (1 = rural; 0 = urban). The provincial random effects are denoted by v_p .

Second, I use the estimates $\hat{\alpha}_i$, $\hat{\beta}_j$, $\hat{\gamma}_k$, $\hat{\delta}_r$, and $\hat{v}_p$ from Eq. (1) to compute the probability of being left-handed for each of the 5,040 age $\times$ sex $\times$ education $\times$ residence $\times$ province cross-tabulated categories as:

$$\text{logit}(\hat{P}_{ijkp}(y_{ijkp} = 1)) = \sum_{45-49}^{85+} \hat{\alpha}_i \text{age}_i + \hat{\beta}_j \text{sex}_j + \sum_{\text{none}}^{\text{college}+} \hat{\gamma}_k \text{education}_k + \hat{\delta}_r \text{residence}_r + \hat{v}_p \quad (2)$$

where $\hat{P}_{ijkp}$ denotes the predicted probability of being left-handed for an individual of age group i , sex j , educational attainment k , and residence r in province p .

Third, I compute the provincial left-handed prevalence by summing the predicted individual probabilities of being left-handed over all cross-tabulated categories in a given province, weighted by the population size in that province (post-stratification weighting). Pop_{ijkp} is the population size of people of age group i , sex j , educational attainment k , and residence r in province p . The left-handed prevalence rate at the provincial level is:

$$\hat{p}_p = \frac{\sum_i \sum_j \sum_k \sum_r \hat{P}_{ijkp} \times \text{Pop}_{ijkp}}{\sum_i \sum_j \sum_k \sum_r \text{Pop}_{ijkp}} \times 100\% = \frac{\sum_i \sum_j \sum_k \sum_r \hat{P}_{ijkp} \times \text{Pop}_{ijkp}}{\text{Pop}_p} \times 100\%, \quad (3)$$

where Pop_p is the total population size of province p .

For the sake of comparison, I also calculated the design-based direct survey estimates of the left-handed prevalence rates at the provincial level. For the design-based estimates, I calculated the standard ratio mean estimator, which is the ratio of the Horvitz–Thompson estimator of the left-handed population to the Horvitz–Thompson estimator of the total population (Heeringa et al., 2010). The Horvitz–Thompson estimator involves the survey design, the sampling weights, and the non-response weights in the China Health and Retirement Longitudinal Study. Combining the design-based and the model-based methods, applied on self-reported dominant hand and grip strength, I obtained four estimates of left-handed prevalence at the provincial level.

4. Results

4.1. Descriptive statistics

Table 1 presents the frequency distributions of left-handedness and the independent variables in the China Health and Retirement Longitudinal Study sample. The sample comprises as many men as women, 74.3% middle-aged respondents of 45–64 years old, and nearly 90% poorly educated respondents who did not attend high school. The unweighted sample comprises 63.2% rural respondents; the weighted sample 50.5%. In both samples, the prevalence rate of left-handers is 7.5% for self-reported dominant hand and 28% for grip strength, which indicates that the two measurements of individual handedness are not equivalent. No clear distribution appears for left-handed prevalence by age, sex, education, or rural-urban residence.

4.2. Estimations

Table 2 reports regression coefficient estimates from Eq. (1). Respondents over 70 years of age are more likely to be left-handed; men more than women; less educated more than more educated. There is no significant difference between rural and urban residents. The variance of the provincial random intercept is statistically significant. Only 2% of the residual variance ($=0.08/(0.08 + \pi^2/3)$) is due to between-province variation, which is small, as it is common with two-level random-intercepts logistic regression (Snijders and Bosker, 1999).

The results differ slightly when using grip strength to classify individual handedness. The difference between respondents over 70 years and those aged 45–49 years is no longer significant. Those aged 55–59 years are more likely to be left-handed. Men and women are no longer significantly different. The negative association between educational attainment and left-handedness still holds, except for the most educated group, which is not significantly different from the illiterate group. Grip strength is thus less characterized by age and sex.

Figure 1 compares the kernel density distributions of the four sets of estimates using design- versus model-based small-area estimation methods and self-reported versus grip-strength measures of handedness. First, consistently with the descriptive statistics in Section 4.1, grip strength leads to higher estimates of left-handed prevalence than self-reported dominant hand, be it with design-based estimation or with model-based estimation. For self-reported dominant hand, both design-based and model-based estimates of left-handed prevalence rates at the provincial level are mostly below 15%. For grip strength, both design-based and model-based estimates of left-handed prevalence rates are above 20%. This contrast indicates that a subjective measure of individual handedness may lead to underestimates of left-handed prevalence. Second, the model-based estimates have smaller variances than the design-based estimates. When using self-reported dominant hand, the standard deviation of the model-based estimates is 0.9% of

Table 1. Descriptive statistics for the variables used in the small-area estimation of left-handed prevalence among Chinese adults aged over 45 years.

	Left-handed prevalence					
	Unweighted %		Self-report		Grip strength	
	Unweighted %	Weighted %	Unweighted %	Weighted %	Unweighted %	Weighted %
Total			7.4	7.9	29.0	28.6
Age (in years) in 2010						
45–49	19.7	21.8	6.5	7.2	25.8	28.0
50–54	16.5	15.8	7.7	7.3	29.6	29.2
55–59	21.6	21.8	6.9	8.0	30.4	28.1
60–64	16.5	14.5	6.9	6.9	28.0	28.0
65–69	11.1	10.4	6.3	9.6	30.2	27.9
70–74	7.3	7.5	7.7	6.6	32.3	31.6
75–79	4.6	4.9	8.2	10.9	28.5	30.0
80–84	2.0	2.5	5.6	4.5	28.5	26.3
≥85	0.7	0.9	2.3	1.2	31.0	40.4
Sex						
Women	52.0	51.5	6.6	6.4	28.0	28.0
Men	48.0	48.5	7.3	8.9	30.0	29.3
Educational attainment						
None	28.9	25.8	7.9	8.1	30.4	30.3
Primary school	40.2	37.9	6.6	7.5	29.4	29.3
Middle school	20.0	22.2	6.7	8.2	27.7	26.4
High school	9.3	11.5	6.4	6.5	26.1	25.6
College or above	1.5	2.5	4.7	3.6	24.5	34.1
Residence						
Urban	36.8	49.5	6.5	8.3	27.6	27.8
Rural	63.2	50.5	7.2	6.9	29.8	29.4
Total number of respondents	12,598	489,838,000	13,027	508,067,435	12,607	491,560,623

Table 2. Regression coefficients in the multilevel logistic models of being left-handed among Chinese aged over 45 years. Standard errors in parentheses.

	Left-handed by self-report	Left-handed by grip strength	
Age group (reference: 0 for 45-49 years)			
50-54	-0.11 (0.11)	0.06 (0.09)	
55-59	-0.06 (0.17)	0.14 (0.08)	*
60-64	0.00 (0.15)	0.02 (0.09)	
65-69	-0.09 (0.17)	0.08 (0.10)	
70-74	-0.27 (0.14)	0.12 (0.11)	**
75-79	0.33 (0.19)	0.04 (0.15)	*
80-84	-0.22 (0.41)	-0.07 (0.17)	
>=85	-1.86 (0.66)	0.38 (0.29)	**
Men (reference: 0 for women)	0.35 (0.09)	0.10 (0.08)	**
Education (reference: 0 for none)			
Primary school	-0.33 (0.10)	-0.13 (0.06)	**
Middle school	-0.44 (0.15)	-0.17 (0.09)	*
High school	-0.48 (0.23)	-0.32 (0.09)	**
College or above	-1.20 (0.43)	-0.09 (0.29)	**
Rural residence (reference: 0 for urban)	-0.11 (0.10)	0.07 (0.07)	
Constant	-2.25 (0.17)	-0.97 (0.11)	**
Variance of provincial random intercepts	0.08 (0.03)	0.04 (0.05)	

*: significant at the 10% level

**: significant at the 5% level.

the population being left-handed at the provincial level, while that for the design-based estimates is 2.9% of the population being left-handed (Table 3). When using grip strength to classify individual handedness, the standard deviation of the model-based estimates is 3.3% of the population being left-handed, while that for the design-based estimates is 6.5% of the population being left-handed. These differences come from the pooling from other small areas, which reduces the variability in estimating the quantity of interest for a given area.

The lack of overlap between the marginal distributions of small-area estimates for self-reported dominant hand and those for grip strength does not mean a low degree of concordance between the joint distributions. Figure 2 shows the pairwise scatter plots for different estimates of left-handed prevalence at the provincial level,

Figure 1. Kernel densities of the small-area estimates of left-handed prevalence at the provincial level among Chinese aged 45 years and over.

Table 3. Descriptive statistics for different small-area estimates of left-handed prevalence among Chinese aged over 45 years at the provincial level.

	Mean	Standard deviation	Minimum	Median	Maximum	Interquartile range	Total number of provinces
<i>Design-based estimates of left-handed prevalence at the provincial level (in %)</i>							
Left-hand dominance by self-report	8.0	2.9	1.4	7.5	13.0	4.4	28
Left-hand dominance by grip strength	27.6	6.5	5.5	28.8	39.9	6.1	28
<i>Model-based estimates of left-handed prevalence at the provincial level (in %)</i>							
Left-hand dominance by self-report	5.3	0.9	3.1	5.3	7.3	1.2	28
Left-hand dominance by grip strength	26.5	3.3	15.8	26.9	33.9	3.7	28

with the linear regression lines and the 95% confidence intervals. The measurement used for handedness matters more than the estimation method. The design- and model-based estimates concord the most with grip strength (panel e), followed by the design- and model-based estimates with self-reported dominant hand (panel b). The design-based estimates with self-reported dominant hand and the model-based estimates with grip strength concord the least, with a correlation of 0.25 and a standard error of 0.19 (panel c). The correlation between the design-based estimates with grip strength and the model-based estimates with self-reported dominant hand has a correlation of 0.53 and a standard error of 0.17 (panel d).

Figure 2. Pairwise correlations between different small-area estimates of left-handed prevalence among Chinese aged 45 years and over at the provincial level ($N = 28$ provinces).

Figure 3 shows three clusters of high left-handed prevalence rates: one in southwest China, without Tibet where no data are available, one in northwest China, in particular the Xinjiang Uyghur Autonomous Region, the third in Shaanxi, Shanxi, and Hubei in northern central China. The rebellious traditions in these provinces may have been accompanied by greater tolerance for left-handedness.

Figure 3. Small-area estimates of left-handed prevalence among Chinese aged 45 years and over at the provincial level ($N = 28$ provinces).

5. Conclusion

I have used the nationally representative China Health and Retirement Longitudinal Study to estimate the geographic variation of the prevalence in left-handedness. The design-based and model-based small-area estimates of individuals' handedness, using measures of self-reported dominant hand and hand grip strength, allowed me to produce four sets of estimates of left-handed prevalence for 28 out of 31 provinces. The estimates concord with one another, with pairwise correlations between 0.25 and 0.93. My estimates of left-handedness are higher than those reported by Teng et al. (1976), Li (1983), and Hoosain (1990). The differences are due to differences in sampling, measurement of handedness, and estimation method. Areas populated by minorities and areas with a revolutionary history have the highest prevalence rates. The between-province differences in the prevalence of left-handedness reveal that the tolerance for this trait is heterogeneous in China.

I used a population-based, nationally representative sample. Unlike previous studies where the problem of sampling bias cannot be remedied by simply recruiting a large total number of participants, the sampling design of China Health and Retirement Longitudinal Study and its quality control of data collection (Zhao et al., 2013b, 2014) allowed me to obtain results representative of the Chinese middle-aged and older adult population.

There are many more left-handed people in China than usually portrayed. The conventional belief that only 1% or fewer Chinese people are left-handed (Kushner, 2013) originates from a survey in the early 1980s led by a psychologist (Li, 1983). It is unclear how accurate or reliable Li's estimate is due to restricted access to his data and lack of proper documentation. In Western countries, the prevalence of left-handedness is often larger among younger age cohorts than among older cohorts (Dellatolas et al., 1991; Gilbert and Wysocki, 1992; Hugdahl et al., 1993). If the same age trend holds among the Chinese population, then it is possible that there are as many, if not more, left-handed people in China as in western countries. As cultural discrimination against left-handedness gradually declines in China, especially in urban areas (Kushner, 2013), more left-handed children will grow up without being forced to switch hand. Another implication pertains to the significance of geographic variation. As pointed out by Kushner (2013), countries like China are diverse and the prevalence of left-handedness varies from one region to another and even within the same regions, by local culture, ethnicity, religious practice, and socio-economic development. Treating the Chinese population as a homogeneous group runs the risk of ignoring substantial heterogeneity in the prevalence of left-handedness and drawing wrong conclusions.

Among limitations, the sub-national level reflected by the China Health and Retirement Longitudinal Study may not be representative, even after statistical adjustment. The young are not representative either. There is no better data

source to perform robustness or sensitivity analysis. Despite these limitations, I managed to combine population-based survey data with small-area estimation methods to quantify geographic variation in the prevalence of left-handedness and to highlight geographic heterogeneity with regard to left-handedness.

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