Month of Birth, Environmental Exposures, and Adult Health in Six Developing Countries

Jessica Y. Ho[1]

University of Pennsylvania

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Abstract

Previous studies have used season of birth as a proxy for early life conditions to examine their association with adult health outcomes. However, no direct tests of the importance of environmental conditions in early life have been performed. Climate conditions influence infectious disease exposure and nutrition, and they are particularly important in developing countries lacking widespread access to refrigeration, clean water, and sanitation. This paper examines the association between environmental exposures experienced in early life and adult health in six developing and newly industrialized countries: India, China, Ghana, Mexico, Russia, and South Africa. Measures of adult health status include biomarker levels, chronic conditions, and functional limitations. I also explore the mediating effects of socioeconomic variables, including individuals' own education and parental education. These analyses contribute to further theoretical refinements and shed light on the health of aging populations in developing countries.

[1] Population Studies Center, 239 McNeil Building, 3718 Locust Walk, Philadelphia, PA, 19104. E-mail: yjho@sas.upenn.edu.

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Introduction

The importance of environmental conditions experienced in early life for health over the life course is understudied. Environmental conditions are important because of their potential to influence infants' disease environment and nutritional intake, and they are likely to exert particularly strong effects in developing countries lacking widespread access to refrigeration, clean water, and sanitation. Infectious and parasitic diseases are hypothesized to be among the most relevant post-birth exposures. High temperature and rainfall levels can produce conditions that are particularly conducive to the spread of infectious diseases such as malaria, dengue, dysentery, cholera, and diarrhea (McEniry and Palloni 2010). They can do this through several mechanisms. For example, changes in temperature and rainfall can shorten pathogens' incubation periods, contributing to foodborne illness. They can also provide habitats for and expand the range of disease vectors like mosquitoes, flies, and rodents, and they can contribute to the spread of waterborne diseases through flooding and contamination of water sources (e.g., facilitating fecal-oral disease transmission). Greater exposure to these diseases in infancy may affect later life health outcomes through scarring and inflammatory processes or acquired immunity (Elo and Preston 1992; Preston, Hill, and Drevenstedt 1998; Finch and Crimmins 2004).

Previous studies have used season of birth as a proxy for early life conditions to examine their association with adult health outcomes. However, no direct tests of the effect of environmental conditions on later life health have been performed. This study aims to fill that gap using data on climate conditions experienced in the months directly preceding and following birth. This paper has two main aims: (1) to estimate the associations between month of birth and adult health outcomes in six developing and newly industrialized countries, and (2) to test whether environmental conditions influencing exposure to infectious and parasitic diseases and nutritional intake during gestation and infancy affect adult health outcomes in India. These analyses have the potential to contribute to further theoretical refinements and to shed light on the determinants of health among aging populations in developing countries.

Background

Early Life Conditions and Health Over the Life Course

There exists a rich literature on how the conditions experienced by individuals early in life have the potential to affect later life health outcomes. For example, Preston, Hill, and Drevenstedt (1998) offer a typology of relations between mortality conditions experienced in childhood and those experienced in adulthood: scarring, correlated environments, acquired immunity, and selection. Exposures generally fall under two broad categories: those taking place *in utero* and those taking place in infancy or childhood. Barker's fetal origins hypothesis (e.g., Barker and Osmond 1986; Barker et al. 2002) posits that adverse nutritional conditions experienced *in utero* can "program" organ systems, predisposing the individuals experiencing unfavorable conditions to develop chronic disease (particularly cardiovascular disease) in adulthood. Finch and Crimmins (2004) hypothesize that exposure to infectious diseases in early life sets off inflammatory processes, which in turn lead to the development of chronic diseases in adulthood. Examples of early-life infections that have been linked with later morbidity, particularly cardiovascular and respiratory diseases, cancer, and diabetes, include tuberculosis, hepatitis B, streptococcal infections, and diarrhea and enteritis (Elo and Preston 1992).

Findings concerning the effects of prenatal exposures on later life health outcomes have been mixed. Several of these studies have examined the effects of prenatal exposure to famines and the 1918 influenza pandemic on later life health and socioeconomic outcomes (e.g., Stanner et al. 1997; Roseboom et al. 2001; Almond 2006). Several empirical studies have documented the impact of postnatal early life conditions on a wide array of adult health outcomes in both developed and developing countries (e.g., Haas 2008; Monteverde, Noronha, and Palloni 2009; Case and Paxson 2010; Huang, Soldo, and Elo 2011). At times, the effects of these early life conditions have operated in unexpected directions. For example, McDade et al. (2009) found that higher levels of microbial exposures in childhood were associated with lower levels of adult C-reactive protein, a marker of inflammation.

Month and Season of Birth

Many scholars, one of the earliest being Huntington (1938), have focused on the effects of month or season of birth as a proxy for actual exposures. Relative to birth weight, month of birth is regarded as being less susceptible to selection biases and to influence by socioeconomic factors. In addition, while birth weight captures only prenatal influences, month of birth serves as an indicator of seasonal influences operating during pregnancy and the first year of life (Doblhammer 2004). Doblhammer (2004)'s comprehensive study found distinctive life span patterns by season of birth in developed countries and month-of-birth patterns for several causes of death, including certain cancers, circulatory diseases, influenza, pneumonia, and chronic respiratory diseases in the United States. McEniry and Palloni (2010) examined the effects of seasonal exposures to poor nutrition and infectious diseases during late gestation in a sample of older Puerto Ricans. In this study, season of birth effects were hypothesized to derive from seasonal variation in parental employment and exposure to infectious and parasitic diseases during the hurricane season. Controlling for childhood socioeconomic conditions, childhood health conditions, and adult risk factors, individuals born in rural areas during high exposure periods were at greater risk of developing heart disease (Ibid.). Particularly relevant for this study (see Case Study section below), Lokshin and Radyakin (2012) examined the relationship between month of birth and child health outcomes using the India National Family Health Survey. They found that children born during monsoon months have lower anthropometric scores compared to children born during the fall-winter months (Ibid.). To the best of my knowledge, however, no studies have examined the effects of being born during the monsoon season on later life health outcomes.

Contribution

Previous studies have examined early life conditions using birth month as a proxy for early life exposures. Among these, relatively few of them (likely due to issues relating to data availability) have examined associations between month or season of birth and adult health outcomes in developing countries. In these studies, it is often difficult to establish the critical exposure period, since month of birth captures both pre- and postnatal influences. Furthermore, no *direct* tests of the importance of environmental conditions in early life have been performed. In this study, I combine data on climate conditions corresponding to the months directly preceding and following birth with high quality datasets on adult health outcomes to investigate whether such exposures matter for adult health and whether the timing of these exposures (i.e., whether they are experienced *in utero* or during the immediate post-birth period) matters. Comparisons can be made among the six developing countries included in the datasets as well as to prior studies of season of birth effects in both developing and developed countries. These analyses have the potential to enhance our understanding of the pathways linking early life exposures to health over the life course.

Data and Methods

Data

The WHO Study on Global Ageing and Adult Health (known as SAGE) composes the primary datasets that will be used for this study. They are modeled after the Health and Retirement Study, English Longitudinal Study of Ageing, and World Health Survey. The samples are nationally representative and consist of respondents aged 18+, with an emphasis on the population aged 50+. The first wave was fielded between 2007 and 2010 in six countries: China, Ghana, India, Mexico, Russia, and South Africa. In addition to collecting information on respondents' sociodemographic characteristics, SAGE also collects information on chronic conditions, functional limitations, and anthropometrics, performance tests, and biomarkers. This dataset has many strengths: it includes information on respondents' geographic location and month of birth, which are both rare and essential to this study; it collects measured as well as self-reported health indicators; and it is very recent, allowing me to assess the current state of health and aging in developing countries. In addition, the questionnaires were designed to be fielded consistently across the six SAGE countries. SAGE is designed to be a longitudinal survey, with waves 2 and 3 to be fielded in 2012 and 2014 (subsequent waves are planned to be implemented every 2 years). While the analyses planned for this study are intended to examine the effect of early life conditions on health conditions at a point in time, the longitudinal design of this study allows for the possibility of looking at the relationship between early life conditions and changes in health status over time once these follow-up surveys are fielded.

The second dataset that will be used is the Climate Research Unit (CRU) TS2.1 dataset, which is publicly available through the Indian Meteorological Department (IMD) and collected by the Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia. This dataset contains monthly mean temperature (in degrees Celsius) and precipitation (in millimeters) measures for selected districts in 35 Indian states from 1901-2002. District-wise data are produced from interpolations based on 0.5 degree latitude-longitude climate grids (Mitchell and Jones 2005). I will link these data to the SAGE India dataset by matching on month, year, state, and district. Meteorological data for the other five SAGE countries, particularly such a long time series, have been difficult to come by, but it may be possible to reproduce these analyses in the other countries in future work.

Health Measures

A range of morbidity measures, both measured and self-reported, serve as the main outcomes of interest in these analyses. **Table** 1 shows the biomarker measures and high risk cutpoints used in this study. The high risk cutpoints are taken from the recommendations of the World Health Organization, National Institutes of Health, or previously published studies. However, there is some evidence that the associations between biomarkers and health outcomes may differ across populations. For example, WHO (2004) and Misra et al. (2006) suggest that Asian populations may have lower cutpoints for body mass index (BMI) and waist circumference. However, the WHO (2004) did not issue cutpoints for specific Asian populations, and epidemiological studies have proposed several different thresholds. I will strive to incorporate these lower cutpoints either in the final analyses or as part of a sensitivity analysis.

Table 1. Biomarker Measures and High Risk Cutpoints

Measure	High Risk Cutpoint	Source
Body mass index (BMI)[2]	Obese, BMI ≥ 30 kg/m^2	A
Diastolic blood pressure[3]	> 90 mm Hg	B
Height		
Hip circumference		
Pulse rate[3]	≥ 90 beats/min	C
Systolic blood pressure[3]	> 140 mm Hg	B
Waist circumference	> 102 cm (M), > 88 cm (F)	D
Waist to hip ratio	> 0.90 (M), > 0.85 (F)	C

Sources: (A) WHO (2012b); (B) Crimmins et al. (2005); (C) Seeman et al. (2008); (D) NHLBI

Questions eliciting information on chronic diseases are in the format: "Have you ever been diagnosed with" or "Have you ever been told by a health professional that you have had" a particular condition. These conditions include: angina, arthritis, asthma, chronic lung disease, depression, diabetes, hypertension, and stroke. Self-rated health is measured using a five-point scale where the possible responses are: very good, good, moderate, bad, or very bad. Respondents are coded as having poor self-rated health if they rated their health as being "bad"

[2] Calculated from respondents' measured height and weight.
[3] Average of three measurements used.

or “very bad.” Data are also collected on mobility and both basic (ADL) and instrumental (IADL) activities of daily living. Questions cover a wide variety of tasks, including respondents’ ability to climb a flight of stairs, perform self-care tasks, use the toilet, extend arms above the shoulders, and walk one meter. Responses are on a five-point scale: none, mild, moderate, severe, and extreme/cannot do, and respondents coded as having difficulty with a task if they report having “severe” or “extreme” difficulty performing the task. While the reporting of chronic conditions and other health measures may be dependent on respondents’ interactions with health care professionals and health knowledge, the collection of measured biomarkers allows for the examination of the relationship between early life conditions and health outcomes which are not dependent on individuals’ interactions with the health care system.

Methods

I estimate logistic and linear regression models (depending on the outcome of interest) for each country. All models are estimated using sample weights and include controls for age group and sex. The dependent variables are adult health outcomes which, based on the existing literature, we expect to be related to early life exposures. One predictor variable of interest is month or season of birth, and the coding of season of birth is done on a country-specific basis. For example, India has a monsoon season lasting from June to September, and China’s climate is also influenced by monsoon winds. While parents may be aware that certain seasons provide more or less favorable conditions for infants, it is reasonable to assume that month of birth is plausibly exogenous. While the primary predictor variables of interest are those capturing environmental conditions, I begin with estimating the associations between month or season of birth and adult health in these six developing countries. As noted above, nationally representative surveys collecting information on both month of birth and adult health were not widely available in developing countries until recently. Documenting these patterns will allow for comparisons to previous studies of both developed and developing countries. Comparing these results to those obtained using direct measures of environmental exposures will help clarify which exposures matter among the wider set of exposures hypothesized to be captured by the month of birth proxy. It will also allow us to assess whether direct measures provide any additional leverage relative to proxy measures.

Case Study: India

In the preliminary results reported below, season of birth is used as the main predictor variable. India has four well-defined seasons: winter, January-February; summer, March-May; monsoon, June-September; and post-monsoon, October-December (see **Table 2** for the season of birth distribution) (Attri and Tyagi 2010). In addition to incorporating information on climate conditions at time of birth from another dataset (see below), I plan to use an alternate coding in future analyses which maximizes the information available from the month of birth variable and takes into account individuals' months of exposure to the monsoon season. For example, assuming an average gestation period of 9 months, an individual born in January would have 0 months of exposure in the third trimester and 0 months of exposure in the first three months after birth to the monsoon season. An individual born in June would have no exposure in the third trimester (or 0.5 months, depending on assumptions made regarding whether individuals are born at the beginning, end, or middle of the month) but 3 (or 2.5) months of exposure in the first three months after birth, an individual born in October would have 2 (or 2.5) months of exposure in the third trimester and 0 months of exposure in the first three months after birth, and so on.

Table 2. Season of Birth Distribution, SAGE Wave 1, Indian Males and Females Aged 50+, 2007-2010

Season of Birth	**Months**	**Males**	**Females**	**Total**
Winter	January-February	19.5	18.1	19.2
Summer	March-May	24.6	32.1	26.6
Monsoon	June-September	39.8	34.3	38.4
Post-Monsoon	October-December	16.0	15.5	15.9

Source: Attri and Tyagi (2010)

The final analyses will incorporate direct measures of environmental conditions at respondents' time of birth. Climate data for India are available by month and year at the district level. While variation in climate conditions within districts may remain, districts are a much finer unit of analysis than other administrative divisions (e.g., states).[4] Thus, I can test whether rainfall

[4] One limitation is that respondents' current district and state of residence may not correspond to their district and state of birth. However, this is not an unreasonable assumption for respondents who reside in rural areas at the time of survey, although this may result in a select subsample. This can be partially addressed by comparing results based on the entire sample to those based on the subsample of respondents who answer affirmatively to the question "Have you always lived in this village/town/city?" and respondents who respond in the negative but report living "in same community/locality/neighborhood" to the question, "Where were you living before?" (see **Appendix Table 2**).

and temperature conditions at time of birth or during gestation directly affect adult health outcomes. I will also examine whether interactions between these variables matter – e.g., whether high temperatures and heavy rainfall in combination produce particularly hazardous conditions for infants that have consequences for later life health – and whether it is the level of or variability in these indicators that matters.

Assuming an average gestational period of 9 months, respondents can be matched to the climate conditions prevailing during each of the 9 months corresponding to the gestational period, as well as to the climate conditions prevailing during the 30 months directly following birth. The ultimate aim is to arrive at a variable that characterizes conditions in respondents' place of birth at time $t-9, t-8, \ldots, t-1, t, t+1, t+2, \ldots, t+30$, where t is the time of birth being incremented or decremented by one month. This will allow me to determine the periods in the life course during which climate conditions are most salient (insofar as later life health outcomes are concerned).

Climate conditions, and their associated effects on the disease environment, are likely to be particularly relevant for this sample of 50+ year old individuals, who were born prior to 1960. Refrigeration is still not widespread in India: as of 2002, only 3.8% of rural households and 30.0% of urban households reported having a refrigerator (Sharma and Haub 2008).[5] In addition, regional variation in India's climate is quite substantial, allowing for the examination of the effects of experiencing a wide range of temperature and rainfall conditions. Both rainfall and temperature exhibit a large amount of both spatial and temporal variability (Attri and Tyagi 2010). I will also include state fixed effects to control for state-specific conditions that may influence health.

Preliminary Results

Figure 1 shows the month of birth distributions for the population aged 50+ in the six SAGE countries. The profiles are relatively flat for China, South Africa, and Russia, whereas seasonal patterns are more evident for Ghana, India, and Mexico.[6]

[5] Tabulated from the 2002 National Sample Surveys.
[6] It is uncertain how and to what extent these patterns may be influenced by selective survival to age 50. For example, if we expect certain months to be particularly unfavorable to infant survival, we may observe lower frequencies of individuals born in those months. However, if those individuals who survived these adverse conditions were particularly hardy (with respect to mortality risks prior to age 50), the opposite case may result (i.e., higher frequencies of individuals born in those months).

Preliminary results from logistic and linear regression models for India are presented in **Table 3**. Season of birth is the main predictor variable in these regressions, and those born during the monsoon season are the reference category. Summary statistics for this and two other samples are shown in **Appendix Table 1**. The regression results for non-movers (those who have always lived in their current residence) are shown in **Appendix Table 2**.[7]

The preliminary results are fairly consistent with findings from previous studies. The previous literature has emphasized linkages between infectious disease insults early in life and the development of cardiovascular disease later in life, although several studies also find associations between childhood conditions and functional status and disability in adulthood (e.g., Monteverde, Noronha, and Palloni 2009; Huang, Soldo, and Elo 2011). In regressions shown in the first panel of Table 3, in which measured biomarkers are the dependent variables, individuals born during the summer season experience significantly increased odds of being in the high-risk categories for systolic blood pressure and pulse rate relative to those born during the monsoon season. These respondents born during the summer months would have been exposed to monsoon conditions shortly after birth. They also have increased odds of ever having been diagnosed with chronic lung disease. Relative to individuals born during the monsoon season, individuals born in the winter and post-monsoon seasons are significantly less likely to report ever being diagnosed with diabetes at the 5% and 10% significance levels, respectively. For several of the other conditions like arthritis and depression, where we would not expect to observe much of a relationship, there appear to be no significant differences by season of birth. In general, those born during the post-monsoon months appear to be somewhat healthier. The patterns for health status and functional limitations are more ambiguous. Individuals born during the winter season appear to have significantly increased odds of reporting several forms of functional limitation, including carrying things, day to day work, and moving around inside the home.

Next Steps

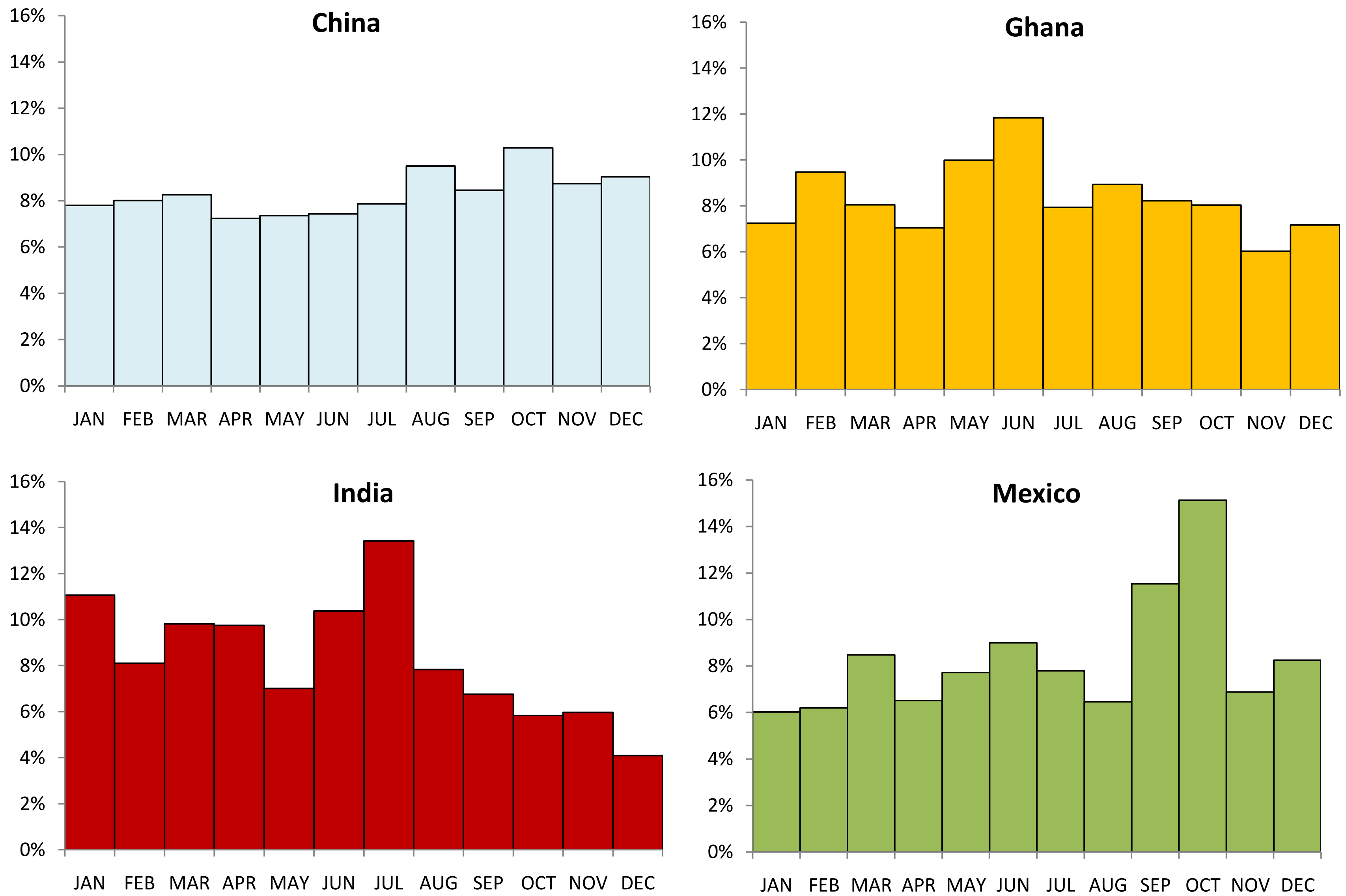
In future analyses, I plan to:

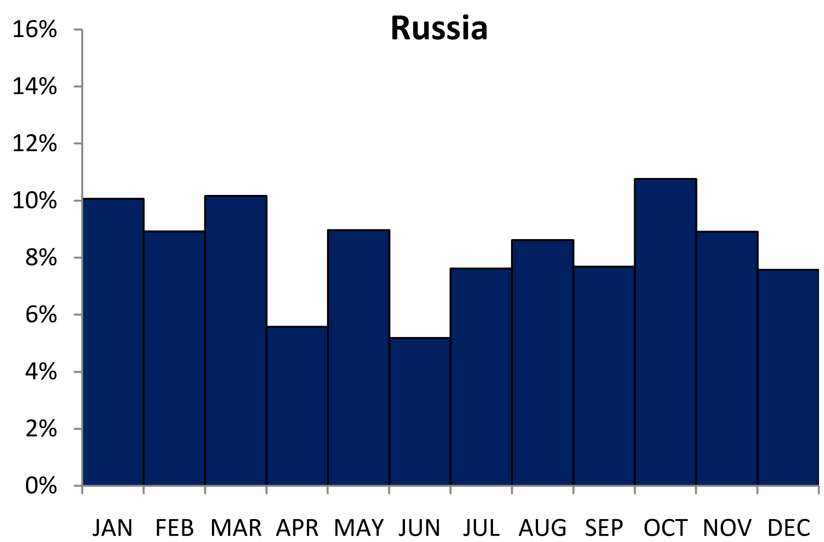
1. Further explore and interpret these results using the life course framework;

[7] The results presented in Table 3 and Appendix Table 2 are highly similar.

2. Examine the associations between adult health and month of birth in the other five SAGE countries;
3. Merge the climate and health datasets and estimate the relationships between health and climate conditions (precipitation and temperature measures) prevailing in the months directly preceding and following respondents' time of birth in India. I will also examine whether the effects of these early life conditions are mediated by intervening variables such as respondents' own education and their parents' education.

Figure 1. Month of Birth Distribution, SAGE Wave 1, Males and Females Combined Aged 50+, 2007-2010




Russia
16%
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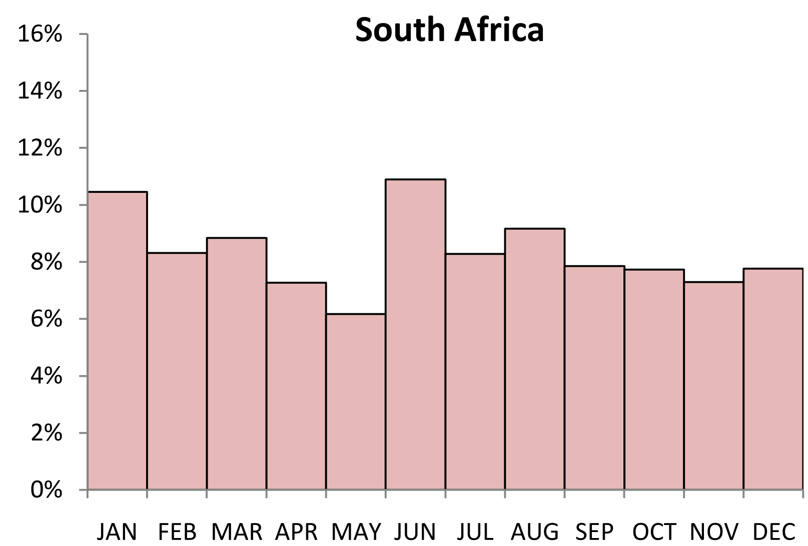
South Africa
16%
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JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Table 3. Coefficients and Odds Ratios from Linear and Logistic Regression Models Predicting Health Outcomes by Season of Birth, SAGE Wave 1, Indian Males and Females Aged 50+, 2007-2010[8]

	Season of Birth				
	Winter	**Summer**	**Monsoon**	**Post-Monsoon**	*N*
Biomarkers[9]					
Height (m)‡	-0.012	-0.008	ref	-0.010	1894
High risk diastolic blood pressure	1.209	1.375	ref	0.935	1906
High risk pulse rate	1.239	1.657*	ref	1.060	1905
High risk systolic blood pressure	1.390	2.009***	ref	0.963	1913
High risk waist circumference	1.248	1.368	ref	1.380	1887
High risk waist to hip ratio	1.006	0.966	ref	1.146	1887
Hip circumference (cm) ‡	-2.120+	-0.539	ref	-0.295	1894
Obese (BMI $\geq$ 30 kg/m^2)	0.431	1.261	ref	0.842	1878
Waist Circumference (cm) ‡	-1.842	-0.430	ref	-0.190	1894
Chronic Conditions					
Angina	0.521	1.218	ref	1.104	1936
Arthritis	1.006	0.838	ref	0.682	1954
Asthma	1.531	0.924	ref	1.126	1946
Chronic lung disease	0.994	2.343**	ref	0.942	1936
Depression	0.832	1.052	ref	0.649	1936
Diabetes	0.534*	0.717	ref	0.590+	1946
Hypertension	1.153	1.325	ref	1.231	1953
Lost all natural teeth	0.567+	0.703	ref	0.851	1954
Stroke	2.871+	2.111	ref	2.948*	1946
Health Status and Functional Limitations					
Poor self-rated health[10]	1.446	1.314	ref	1.107	1954
Difficulty with the following tasks in the last 30 days:[11]					
Carrying things	1.911**	1.188	ref	1.914*	1913
Climbing a flight of stairs	1.178	1.265	ref	1.465	1737
Day to day work	2.425**	1.051	ref	2.150	1938
Extending arms above shoulders	1.208	1.083	ref	0.519	1953
Getting dressed	1.455	0.826	ref	0.775	1951
Getting to and using toilet	0.734	0.666	ref	0.697	1948

[8] All models are estimated using sample weights and include controls for age group and sex. Linear regression models are estimated for height, hip circumference, and waist circumference. All other models are logistic regression models with binary dependent variables.
[9] High risk cutpoints are as defined in Table 1.
[10] Self-rated health was coded on a 5-point scale: very good, good, moderate, bad, and very bad. Respondents were coded as having poor self-rated health if they rated their health as being “bad” or “very bad.”
[11] These variables were coded on a 5-point scale: none, mild, moderate, severe, and extreme. Respondents were coded as having difficulty with the task if they reported having “severe” or “extreme” difficulty.

Getting up from lying down	1.196	0.725	ref	0.0946***	1951
Moving around inside the home	3.241*	1.890	ref	0.844	1944
Picking things up	0.672	0.706	ref	0.294+	1952
Self-care	1.210	1.216	ref	0.629	1954
Sitting for long periods	1.807+	1.453	ref	0.935	1950
Standing for long periods	1.621+	0.923	ref	1.148	1941
Standing up from sitting down	1.944+	1.521+	ref	1.475	1946
Stooping, kneeling or crouching	1.148	1.107	ref	1.067	1942
Walking 1 km	1.101	0.968	ref	1.356	1879
Walking 100 m	0.992	1.255	ref	1.147	1927
Washing/bathing	1.151	0.442+	ref	0.396	1942

+ p<0.10, * p<0.05, **p<0.01, *** p<0.001
‡ linear regression

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Appendix

Appendix Table 1. Summary Statistics, Distribution or Mean (SE), SAGE Wave 1, Indian Males and Females Aged 50+, 2007-2010[12]

	Total Sample[13]			**Sample 1**[14]			**Sample 2**[15]		
	M	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**
	51.1%	48.9%		74.0%	26.0%		87.7%	12.3%	
N	3616	3534	7150	1324	630	1954	1115	236	1351
Sociodemographic Characteristics									
Age									
50-54	23.3	23.8	23.6	26.0	28.4	26.6	26.9	31.9	27.5
55-59	27.5	23.0	25.3	28.1	24.1	27.1	29.3	24.9	28.8
60-64	15.0	18.1	16.5	13.3	14.1	13.5	12.4	17.5	13.1
65-69	14.5	13.5	14.0	13.8	14.4	14.0	12.8	10.0	12.4
70-74	10.3	10.9	10.6	12.8	11.8	12.5	12.6	10.8	12.4
75-79	5.6	4.9	5.2	3.7	3.5	3.6	3.8	3.5	3.8
80-84	2.5	3.3	2.9	1.7	2.5	1.9	1.8	1.4	1.7
85-89	0.8	1.3	1.1	0.4	0.1	0.3	0.3	0.0	0.3
90+	0.4	1.3	0.8	0.3	1.2	0.6	0.1	0.0	0.1
Education (highest level completed)									
Less than primary	17.8	28.0	20.6	8.6	17.8	10.2	9.2	13.8	9.6
Primary school	26.2	41.3	30.4	18.4	33.2	20.9	18.8	28.8	19.7
Secondary school	22.8	15.8	20.9	24.1	15.3	22.7	24.7	22.0	24.4
High school	20.8	9.5	17.6	27.7	18.7	26.2	27.5	21.5	27.0
College/ university	8.0	4.5	7.0	13.5	12.1	13.2	12.8	13.4	12.8
Post-graduate degree	4.5	0.9	3.5	7.7	2.8	6.9	7.0	0.6	6.4
Season of birth									
Winter	19.5	18.1	19.2	19.5	18.1	19.2	19.0	16.6	18.7
Summer	24.6	32.1	26.6	24.6	32.1	26.6	22.6	30.8	23.6
Monsoon	39.8	34.3	38.4	39.8	34.3	38.4	42.0	39.8	41.7
Post-Monsoon	16.0	15.5	15.9	16.0	15.5	15.9	16.5	12.9	16.1

Biomarkers

[12] All models are weighted. Sample sizes will differ slightly depending on missingness for particular variables.
[13] All male and female respondents aged 50+.
[14] Male and female respondents aged 50+ not missing information on age, season of birth, and sex.
[15] Male and female respondents aged 50+ not missing information on age, season of birth, and sex and who were non-movers (have always lived in current residence).

Height (m)									
Mean (SE)	1.634 (0.002)	1.498 (0.002)	1.568 (0.002)	1.648 (0.004)	1.504 (0.004)	1.611 (0.004)	1.648 (0.004)	1.500 (0.006)	1.631 (0.005)
Systolic blood pressure (mm Hg)									
Mean (SE)	121.99 (0.502)	125.63 (0.480)	123.78 (0.399)	123.48 (0.785)	127.02 (0.880)	124.40 (0.670)	122.93 (0.845	124.28 (1.691)	123.09 (0.803)
Normal	82.6	79.9	81.3	81.1	77.6	80.2	82.3	83.3	82.4
High risk	17.5	20.1	18.7	18.9	22.4	19.8	17.7	16.7	17.6
Diastolic blood pressure (mm Hg)									
Mean (SE)	80.36 (0.360)	82.27 (0.355)	81.30 (0.278)	81.26 (0.574)	83.17 (0.619)	81.76 (0.472)	80.97 (0.576)	82.73 (1.107)	81.18 (0.532)
Normal	78.1	76.8	77.5	77.1	74.2	76.3	77.3	77.6	77.4
High risk	21.9	23.2	22.5	22.9	25.8	23.7	22.7	22.4	22.7
Pulse rate (beats/min)									
Mean (SE)	79.82 (0.340)	83.58 (0.472)	81.66 (0.309)	78.76 (0.587)	82.64 (0.716)	79.77 (0.485)	78.89 (0.621)	82.81 (1.592)	79.37 (0.587)
Normal	81.7	75.2	78.5	82.7	78.4	81.6	83.1	77.8	82.5
High risk	18.3	24.8	21.5	17.3	21.6	18.4	16.9	22.2	17.5
Waist circumference (cm)									
Mean (SE)	81.22 (0.386)	80.86 (0.423)	81.05 (0.355)	84.17 (0.599)	84.93 (1.104)	84.36 (0.625)	83.97 (0.556)	86.33 (1.591)	84.25 (0.570)
Normal	96.3	74.9	85.9	95.3	58.9	86.0	96.1	60.9	91.9
High risk	3.7	25.1	14.1	4.7	41.1	14.0	3.9	39.1	8.1
Hip circumference (cm)									
Mean (SE)	87.07 (0.333)	88.58 (0.427)	87.81 (0.341)	89.54 (0.522)	91.20 (1.163)	89.96 (0.584)	89.42 (0.504)	93.00 (1.699)	89.85 (0.547)
Waist-to-hip ratio									
Mean (SE)	0.93 (0.002)	0.92 (0.003)	0.92 (0.002)	0.94 (0.003)	0.93 (0.005)	0.94 (0.002)	0.94 (0.003)	0.94 (0.013)	0.94 (0.003)
Normal	26.2	16.1	21.3	20.5	11.1	18.1	20.4	16.3	20.0
High risk	73.8	84.0	78.8	79.5	88.9	81.9	79.6	83.7	80.1
Body mass index (kg/m^2)[16]									
Underweight	39.8	37.6	38.7	27.9	27.5	27.8	29.5	23.8	28.8
Normal	50.3	45.6	48.0	58.3	47.4	55.5	57.9	50.2	57.0
Overweight	8.1	13.2	10.6	11.3	17.1	12.8	10.3	17.4	11.1
Obese I	1.1	2.4	1.7	1.8	6.7	3.1	1.7	7.9	2.4
Obese II/III	0.7	1.3	1.0	0.7	1.2	0.8	0.6	0.6	0.6
<u>Chronic Conditions (ever diagnosed)</u>									
Stroke									

[16] Underweight (BMI < 18.5), Normal (BMI 18.5-24.99), Overweight (25.0-29.99), Obese I (BMI 30.0-34.99), Obese II/III (BMI ≥ 35.0)

No	97.8	98.3	98.0	97.3	98.3	97.5	97.7	99.3	97.9
Yes	2.2	1.7	2.0	2.7	1.7	2.5	2.3	0.7	2.1
Arthritis									
No	84.5	79.0	81.8	86.2	67.1	81.2	87.1	68.8	84.8
Yes	15.5	21.0	18.2	13.8	32.9	18.8	12.9	31.2	15.2
Asthma									
No	91.0	94.6	92.8	93.4	93.8	93.5	93.8	88.4	93.1
Yes	9.0	5.4	7.2	6.6	6.2	6.5	6.2	11.6	6.9
Angina									
No	93.2	95.8	94.5	90.1	95.8	91.5	89.3	96.3	90.1
Yes	6.8	4.2	5.5	9.9	4.2	8.5	10.8	3.7	9.9
Hypertension									
No	86.2	79.7	83.0	80.0	76.4	79.1	81.1	76.8	80.5
Yes	13.8	20.3	17.0	20.0	23.6	20.9	19.0	23.2	19.5
Chronic lung disease									
No	93.7	97.4	95.5	93.3	98.6	94.7	92.8	99.1	93.6
Yes	6.3	2.6	4.5	6.7	1.4	5.3	7.2	0.9	6.4
Depression									
No	95.8	96.1	95.9	96.1	95.7	96.0	96.2	96.1	96.2
Yes	4.2	4.0	4.1	3.9	4.3	4.0	3.8	3.9	3.8
Lost all natural teeth									
No	86.1	83.6	84.9	87.0	86.6	86.9	86.9	90.1	87.3
Yes	13.9	16.4	15.1	13.0	13.4	13.1	13.1	10.0	12.7
Health Status and Functional Limitations									
Self-rated health									
Very good	2.9	1.4	2.2	5.1	1.7	4.3	5.8	2.3	5.3
Good	33.0	23.6	28.4	36.1	22.4	32.5	36.4	22.3	34.7
Moderate	44.5	49.7	47.1	43.7	51.2	45.6	42.4	51.8	43.6
Bad	18.4	23.1	20.7	14.3	22.8	16.5	14.5	22.1	15.4
Very bad	1.3	2.2	1.7	0.8	1.9	1.1	0.9	1.5	0.9
Difficulty with the following tasks in the last 30 days:									
Carrying things									
None	45.6	32.9	39.4	51.2	36.3	47.4	52.4	44.6	51.5
Mild	24.1	25.3	24.7	21.5	24.1	22.2	20.8	22.4	21.0
Moderate	14.2	16.3	15.3	13.4	14.6	13.7	12.7	14.3	12.9
Severe	11.0	16.9	13.9	9.6	13.6	10.6	9.5	10.2	9.6
Extreme	5.1	8.6	6.8	4.3	11.3	6.1	4.5	8.5	5.0
Climbing a flight of stairs without resting									
None	34.5	20.2	27.7	40.2	24.8	36.6	41.8	26.6	40.1
Mild	25.7	22.7	24.3	24.2	22.6	23.8	23.5	26.9	23.9

Moderate	18.5	19.6	19.0	15.3	21.8	16.8	14.0	17.9	14.5
Severe	15.4	25.7	20.3	15.2	19.2	16.2	15.3	16.6	15.4
Extreme	6.0	11.8	8.7	5.1	11.7	6.6	5.4	11.9	6.2
Day to day work									
None	62.8	45.7	54.4	68.7	50.6	64.0	68.6	56.9	67.2
Mild	21.3	25.6	23.4	17.6	22.5	18.9	17.6	18.0	17.7
Moderate	10.0	15.8	12.9	8.7	16.4	10.7	8.6	15.2	9.4
Severe	4.4	9.3	6.8	3.9	6.6	4.6	3.9	8.0	4.4
Extreme	1.5	3.6	2.5	1.1	3.9	1.8	1.2	1.8	1.3
Extending arms above shoulders									
None	71.8	57.4	64.7	71.9	51.7	66.6	71.5	55.4	69.5
Mild	17.0	23.8	20.3	16.2	25.0	18.4	16.4	25.4	17.5
Moderate	6.7	10.4	8.5	7.3	13.2	8.8	7.7	8.8	7.9
Severe	3.5	7.1	5.3	3.9	9.1	5.3	3.6	8.2	4.2
Extreme	1.0	1.3	1.1	0.8	1.1	0.9	0.8	2.2	0.9
Getting dressed									
None	86.7	81.5	84.2	88.6	83.2	87.2	88.3	85.4	88.0
Mild	8.4	11.0	9.7	6.9	8.8	7.4	7.0	7.6	7.0
Moderate	2.8	3.8	3.3	2.9	5.3	3.5	3.0	5.8	3.3
Severe	1.7	2.3	2.0	1.5	1.7	1.5	1.6	1.3	1.6
Extreme	0.4	1.4	0.9	0.1	1.0	0.4	0.1	0.0	0.1
Getting to and using toilet									
None	75.6	64.8	70.3	76.7	66.6	74.1	76.4	74.9	76.2
Mild	13.9	18.6	16.2	12.4	20.2	14.4	12.1	14.0	12.3
Moderate	5.7	9.3	7.5	5.5	8.3	6.2	6.2	6.3	6.3
Severe	4.0	5.5	4.8	4.7	3.9	4.5	4.5	3.5	4.4
Extreme	0.8	1.7	1.3	0.7	1.1	0.8	0.7	1.3	0.8
Getting up from lying down									
None	63.6	47.4	55.7	66.6	42.7	60.4	67.0	44.2	64.3
Mild	24.3	30.0	27.1	21.6	33.1	24.6	21.3	35.5	23.0
Moderate	9.2	15.9	12.4	9.6	17.0	11.5	9.5	12.3	9.8
Severe	2.5	5.5	4.0	1.9	6.0	2.9	1.8	6.3	2.4
Extreme	0.5	1.1	0.8	0.3	1.2	0.5	0.3	1.7	0.5
Moving around inside home									
None	77.0	66.1	71.7	77.6	65.1	74.4	77.6	66.5	76.2
Mild	14.7	19.7	17.2	13.6	21.2	15.6	13.2	19.5	14.0
Moderate	6.0	8.9	7.4	7.0	8.2	7.3	7.5	9.2	7.7
Severe	1.8	3.9	2.8	1.5	4.3	2.2	1.4	4.3	1.8
Extreme	0.6	1.5	1.0	0.3	1.2	0.6	0.3	0.5	0.3
Picking things up									
None	75.8	69.4	72.7	80.5	75.2	79.1	79.4	77.7	79.2
Mild	14.5	17.8	16.1	10.3	12.4	10.8	10.6	10.3	10.6
Moderate	5.8	7.4	6.6	6.1	8.0	6.6	6.5	6.7	6.5

Severe	2.8	4.6	3.7	2.5	3.0	2.7	2.8	1.6	2.7
Extreme	1.1	0.8	1.0	0.6	1.4	0.8	0.7	3.6	1.1
Self-care									
None	82.2	74.0	78.2	83.0	75.6	81.1	82.6	76.5	81.9
Mild	11.7	15.8	13.7	11.8	13.2	12.2	12.0	13.7	12.2
Moderate	3.8	5.9	4.8	3.5	6.7	4.4	3.8	5.5	4.0
Severe	1.5	3.6	2.5	1.1	3.7	1.7	1.1	4.3	1.5
Extreme	0.7	0.8	0.8	0.6	0.8	0.6	0.5	0.0	0.4
Sitting for long periods									
None	41.6	27.2	34.6	44.0	25.2	39.1	42.5	29.3	40.9
Mild	29.9	30.4	30.1	28.4	27.1	28.0	28.3	24.2	27.8
Moderate	16.1	23.5	19.7	17.0	29.2	20.2	18.2	27.8	19.4
Severe	10.4	17.1	13.7	9.0	14.2	10.3	9.1	16.6	10.0
Extreme	2.1	1.8	1.9	1.6	4.4	2.4	1.9	2.2	1.9
Standing for long periods									
None	31.8	16.6	24.4	36.1	16.9	31.1	36.0	19.4	33.9
Mild	29.3	27.6	28.5	30.7	26.8	29.7	29.9	35.8	30.7
Moderate	20.0	25.1	22.5	16.4	28.6	19.6	16.6	23.0	17.4
Severe	14.8	25.0	19.8	14.0	19.9	15.5	14.4	16.1	14.6
Extreme	4.1	5.7	4.9	2.9	7.7	4.2	3.2	5.6	3.5
Standing up from sitting down									
None	48.4	27.8	38.4	50.6	20.5	42.8	50.5	21.6	46.9
Mild	27.8	30.8	29.2	24.6	37.8	28.0	23.8	40.7	25.9
Moderate	13.3	21.9	17.5	14.4	24.5	17.0	15.1	18.2	15.5
Severe	9.1	17.0	12.9	9.4	13.3	10.4	9.4	16.4	10.3
Extreme	1.4	2.5	1.9	1.1	3.9	1.8	1.2	3.1	1.5
Stooping, kneeling, or crouching									
None	40.6	27.1	34.0	45.5	26.7	40.6	45.4	25.2	43.0
Mild	31.3	31.6	31.4	28.0	34.3	29.6	27.5	38.4	28.8
Moderate	16.1	20.5	18.2	16.2	19.8	17.1	16.9	20.4	17.3
Severe	9.0	17.1	13.0	7.6	14.9	9.5	7.1	13.8	7.9
Extreme	3.0	3.7	3.3	2.8	4.3	3.2	3.1	2.2	3.0
Walking 1 km									
None	34.4	23.0	28.9	39.4	19.1	34.2	39.3	20.6	37.1
Mild	25.0	20.4	22.8	24.7	21.8	24.0	24.9	22.3	24.6
Moderate	18.4	19.4	18.9	17.7	25.7	19.7	16.8	28.8	18.3
Severe	15.5	25.3	20.2	13.6	20.9	15.5	14.3	19.5	14.9
Extreme	6.6	12.1	9.3	4.7	12.5	6.6	4.7	8.9	5.2
Walking 100 m									
None	58.8	31.9	45.7	60.9	39.2	55.3	60.7	40.7	58.3
Mild	20.6	26.6	23.5	16.5	24.4	18.6	16.4	26.4	17.6
Moderate	11.6	20.2	15.8	13.3	18.8	14.7	13.5	17.5	14.0
Severe	6.3	15.8	10.9	6.8	11.1	8.0	7.1	9.5	7.4

Extreme	2.7	5.5	4.1	2.4	6.5	3.5	2.3	6.0	2.8
Washing/bathing									
None	83.5	78.2	80.9	85.2	81.6	84.2	84.6	87.3	84.9
Mild	10.3	13.8	12.0	9.4	11.7	10.0	9.9	8.4	9.7
Moderate	3.6	3.9	3.7	3.2	3.3	3.2	3.1	2.6	3.0
Severe	1.9	2.5	2.2	2.0	2.3	2.1	2.3	1.7	2.2
Extreme	0.6	1.6	1.1	0.2	1.1	0.4	0.2	0.0	0.2

Appendix Table 2. Coefficients and Odds Ratios from Linear and Logistic Regression Models Predicting Health Outcomes by Season of Birth, SAGE Wave 1, Indian Males and Females Aged 50+ Who Have Always Lived in Current Residence, 2007-2010[17]

	Season of Birth				
	Winter	**Summer**	**Monsoon**	**Post-Monsoon**	*N*
Biomarkers[18]					
Height (m) ‡	-0.013	-0.009	ref	-0.012	1312
High risk diastolic blood pressure	1.269	1.680*	ref	0.825	1319
High risk pulse rate	1.049	1.517	ref	0.775	1318
High risk systolic blood pressure	1.325	2.563***	ref	0.761	1319
High risk waist circumference	1.097	1.260	ref	1.984	1307
High risk waist to hip ratio	1.063	1.012	ref	1.173	1307
Hip circumference (cm) ‡	-2.392+	-0.252	ref	-0.003	1312
Obese, BMI ≥ 30 kg/m^2	0.357	2.021	ref	1.206	1306
Waist Circumference (cm) ‡	-2.290+	-0.475	ref	0.287	1312
Chronic Conditions					
Angina	0.538	1.147	ref	1.262	1343
Arthritis	0.858	0.790	ref	0.709	1351
Asthma	1.168	0.880	ref	1.235	1349
Chronic lung disease	1.056	2.761**	ref	0.848	1343
Depression	0.604	1.060	ref	0.676	1343
Diabetes	0.309**	0.685	ref	0.397*	1349
Hypertension	0.853	1.373	ref	1.054	1348
Lost all natural teeth	0.433*	0.824	ref	0.798	1351
Stroke	7.974**	2.606	ref	4.190*	1349
Health Status and Functional Limitations					
Poor self-rated health[19]	1.502	1.192	ref	1.098	1349
Difficulty with the following tasks in the last 30 days: [20]					
Carrying things	2.330**	1.208	ref	2.261*	1332
Climbing a flight of stairs	1.071	1.217	ref	1.402	1232
Day to day work	3.359**	1.728	ref	3.702*	1343
Extending arms above shoulders	1.129	0.835	ref	0.605	1350
Getting dressed	1.559	0.847	ref	0.931	1349
Getting to and using toilet	0.675	0.460	ref	0.829	1348
Getting up from lying down	1.391	0.625	ref	0.151**	1349

[17] All models are weighted and include controls for age group and sex.
[18] High risk cutpoints are as defined in Table 1.
[19] Self-rated health was coded on a 5-point scale: very good, good, moderate, bad, and very bad. Respondents were coded as having poor self-rated health if they rated their health as being “bad” or “very bad.”
[20] These variables were coded on a 5-point scale: none, mild, moderate, severe, and extreme. Respondents were coded as having difficulty with the task if they reported having “severe” or “extreme” difficulty.

Moving around inside the home	1.344	2.038	ref	0.750	1346
Picking things up	0.434	0.742	ref	0.290+	1350
Self-care	2.114	1.003	ref	0.665	1351
Sitting for long periods	1.851	1.283	ref	1.160	1346
Standing for long periods	1.588	0.826	ref	1.435	1342
Standing up from sitting down	2.234	1.207	ref	1.709	1348
Stooping, kneeling or crouching	1.149	1.072	ref	1.253	1346
Walking 1 km	1.117	1.185	ref	1.610+	1312
Walking 100 m	0.868	1.418	ref	1.503	1343
Washing/bathing	1.745	0.455	ref	0.407	1346

+ p<0.10, * p<0.05, **p<0.01, *** p<0.001
‡ linear regression