“In general, how do you feel today?”
Self-rated health in the context of aging in India

Siddhivinayak Hirve
Umeå 2013
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<tr>
<th>Page, line</th>
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<tr>
<td>Page 33, equation (1c, 2c)</td>
<td>( \tau_i^k = v_i^k = \gamma^k X_i ) \hspace{1cm} (1c, 2c)</td>
<td>( \tau_i^k = \gamma^k X_i ) \hspace{1cm} (1c)</td>
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<td>Page 33, 2nd paragraph</td>
<td>....and also forced the response category thresholds to be identical when rating self and all vignettes (1c, 2c). We did a Wald test for threshold parameters ( (\gamma^k) ) of all covariates to be equal to zero (global test for response consistency) and for the threshold parameter of individual covariates to be equal to zero to determine which covariates influenced response consistency.</td>
<td>....and then tested for RC i.e. equality of thresholds derived from the two models ( (\gamma^k = \gamma^k_v, k = 1, \ldots K - 1) ) by comparing the estimates of the response category thresholds identified by the ‘objective measures’ model and the ‘vignettes only’ model.</td>
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Abstract

Background
Most aging research comes from the developed world. Aging research in India is focused on disease states and risk factors. Evidence on elderly health, physical performance and disability to understand the psycho-social or socio-behavioral risk is limited in India. Self-rated health (SRH) is used often in survey settings to quickly assess health status and is known to predict morbidity and mortality. The first wave of the Study on global AGEing and adult health (SAGE) survey provides an opportunity to explore the complex construct of SRH in the context of the aging process in its various key life domains of health, disability, cognition, activities of daily life, work, family, security and well-being in low and middle income settings.

Objectives
This research aims to (a) understand pathways through which the social environment, functional disability, health behaviour and chronic disease experience influence SRH, (b) examine the role of SRH in predicting mortality, (c) validate SRH to improve its inter-personal comparability, and (d) assess how well estimates of SRH derived directly from a ‘small area’ survey compare with ‘small area’ estimates derived indirectly from a ‘large area’ survey.

Methods
The Vadu Health and Demographic Surveillance System (HDSS) monitor health and demographic trends in a rural population of more than 100,000 in 22 villages in India since 2002. The full and short version of the SAGE survey was implemented in Vadu in 2007-09 among 321 and 5432 individuals aged 50 years and above, respectively. A structural equation model tested pathways through which social and biological factors influenced SRH. A Cox proportional hazard model examined the role of SRH as a predictor for mortality. Anchoring vignettes were used to evaluate SRH for reporting heterogeneity. The Hierarchical Ordered Probit model adjusted SRH for reporting heterogeneity. The SRH prevalence estimates for Vadu derived indirectly (indirect synthetic estimate, empirical Bayes estimate, Hierarchical Bayes estimate) from the national SAGE survey were compared with estimates derived directly from the Vadu SAGE survey, using different design and model-based techniques.
Results
Older individuals reported poor SRH compared to those younger. Women rated their quality of life and SRH poorer than men. The effect of age on SRH was mediated through functional disability. Higher socioeconomic status and higher quality of life was in turn associated with better SRH but this relationship lacked statistical significance. Smoking or consumption of tobacco was associated with at least one chronic illness which in turn was associated with poor SRH and quality of life. However the association between chronic illness and SRH and quality of life was not statistically significant. Mortality risk was higher among individuals who reported bad/very bad SRH, disability and lack of spousal support independent of age and sex. There was strong evidence of reporting heterogeneity in SRH that was influenced by age, sex, education and socioeconomic status. The prevalence of ‘good / very good’ SRH was estimated to be 50%. This direct survey estimate compared well with the prevalence estimate of about 45% derived indirectly from model-based small area estimation methods. The indirect synthetic estimate for Vadu (23.2%) was a poor approximation to the direct survey or model-based estimate.

Conclusion
This research establishes the value and utility of SRH as a simple measure of health and predictor of mortality in an aging context. It provides evidence to formulate programs and policies towards an enabling social environment and an ability to function in key life domains of health and well-being. It highlights the need to identify and adjust self-rated responses for interpersonal incomparability prior to making comparisons across individuals or groups of individuals. It highlights the potential of using information from large national surveys by district level managers for planning and evaluation of policies and programs at the district or sub-district level. Finally, this research provides the basis for integrating SRH and related questions into routine HDSS.

Keywords
Self-rated health, quality of life, aging, mortality, disability, reporting heterogeneity, anchoring vignettes, India.
Original papers

This thesis is based on the following papers:


IV. Hirve S, Vounatsou P, Juvekar S, Blomstedt Y, Wall S, Chatterjee S, Ng N. Self-rated health: small area large area comparisons amongst older adults at the state, district and sub-district level in India. (under review) 2013.
Abbreviations and acronyms

CHARLS Chinese Health and Retirement Longitudinal Study
CI Confidence Interval
COURAGE Collaborative Research on Aging in Europe
CSPro Census Survey and Processing System
DAS Disability Assessment Schedule
df degrees of freedom
DIF Differential Item Functioning
DRM Day Reconstruction Method
DSM Diagnostic and Statistical Manual of Mental Disorders
EBLUP Empirical Best Linear Unbiased Predictions
FAS Forskningrådet för Arbetsliv och Socialvetenskap (Swedish Council for Health, Working Life and Welfare)
GIS Geographic Information Systems
GLLAMM Generalized Linear Latent and Mixed Models
GPAQ Global Physical Activity Questionnaire
HART Survey of Health, Aging and Retirement in Thailand
HB Hierarchical Bayes
HDSS Health and Demographic Surveillance System
HOPIT Hierarchical Ordered Probit
HR Hazard Ratio
HRS Health and Retirement Study
IADL Instrumental Activities of Daily Living
ICD International Classification of Diseases
IFLS Indonesian Family Life Survey
INDEPTH International Network for Demographic Evaluation of Populations and Their Health
IRT Item Response Theory
JSTAR Japanese Study on Aging and Retirement
KEM King Edward Memorial
KLoSA Korean Longitudinal Study of Aging
LASI Longitudinal Aging Study in India
LISREL Linear Structural Relations
MHA Mexican Health and Aging study
MLRA Multilevel Regression Analysis
NCD Non-Communicable Diseases
NFHS National Family Health Survey
NIA National Institute on Aging
QOL Quality of Life
RMSEA Root Mean Square Error of Approximation
SAGE Study on Global AGEing and Adult Health
SEM Structural Equation Model
SHARE Study of Health, Retirement and Aging in Europe
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<td>SLI</td>
<td>Standard of Living Index</td>
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<td>TILDA</td>
<td>Irish Longitudinal Study of Aging</td>
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<td>UN</td>
<td>United Nations</td>
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<td>WHO</td>
<td>World Health Organization</td>
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<td>Win BUGS</td>
<td>Windows Bayesian using Gibbs Sampler</td>
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Glossary of terms

Aging – in its broadest sense refers to changes that occur during the lifespan and may include changes like graying of hair which may not affect survival. Senescence, a more precise term, is the progressive decline in bodily functions over time that decreases fertility and increases mortality as one gets older.

Anchoring vignette – refers to a brief description of a hypothetical situation or person that researchers use to correct for inter-personal incomparability of survey responses.

Health and Demographic Surveillance System (HDSS) – refers to a system that monitors health and demographic events in a geographically defined population. Events are captured through periodic surveys of all households or through some active or passive system of collection of information.

Endogenous variable – is a variable that is an inherent part of the system being studied and is determined within the system. It is ‘caused’ by other variables within the causal system. In a graphical representation, a variable that has an arrow pointing towards it is an endogenous variable.

Exogenous variable – is a variable entering from and determined from outside the system being studied. A causal system says nothing about its exogenous variable – its value is given, not analyzed. In a graphical representation, a variable that does not have an arrow pointing towards it is an exogenous variable.

Generalized Linear Latent and Mixed Models (GLLAMM) – are a broad class of multilevel latent variable models for multivariate responses of mixed type including continuous responses, counts, dichotomous and ordered or unordered categorical responses. The latent variables can be assumed to have a discrete or multivariate distribution. Examples include single or multilevel generalized linear models, item response models, multilevel structural equation model, latent class models etc.
**Hazard ratio** – is the instantaneous hazard rate given the exposure divided by the instantaneous hazard rate not given the exposure. The instantaneous hazard rate is the limit of the number of events per unit time divided by the number at risk, as the time interval approaches zero.

**Hierarchical Ordered Probit (HOPIT) model** – is a modification of the standard ordered probit model that incorporates information from vignettes ratings with self-assessment ratings. The model has several components to the likelihood function – the first component estimates the cut-points using vignette ratings, the second component uses ratings on the self-assessment question, the remaining component allows the cut-points to vary by covariates. The HOPIT model allows the vignette component to drive the cut-points, which are then forced to be identical with that for the second self-assessment component.

**Quality of life** – is a construct that goes just beyond health and wealth. It is linked with social and mental well-being, social belonging, education, employment, leisure and recreation. It has been variably used in health care, economics, international development and the field of politics. Quality of life in health care is often regarded in terms of how an individual is affected by an illness or aging. One definition models quality of life on ‘being’, ‘belonging’ and ‘becoming’ – who one is, how is one connected to one’s environment and if and how one achieves one’s own goals and aspirations.

**Latent variable** – refers to an underlying characteristic that cannot be observed or measured. It is hypothesized to exist so as to explain variables such as behavior that can be observed or is manifest.

**Manifest variable** – is an observed variable that is assumed to indicate the presence of an underlying latent variable. It is also referred to as ‘indicator variable’.

**Markov Chain Monte Carlo (MCMC) methods** – are a class of algorithms that construct a Markov chain of random quantities in which each of the simulated value depends on the preceding value. Under specific conditions, this chain of random quantities will converge to a dependent sample of the desired probability distribution.
**Multilevel regression models** – are a generalization of linear regression models where data are organized at more than one level i.e. the model parameters vary at more than one level. Hierarchical models, random effect models, random coefficient models, random slope models, mixed effect models are a type of multilevel regression models.

**Proportional Hazards model** – is a model that allows analyzing the effect of several risk factors on survival. It models the hazard at time $t$ i.e. the probability of the end-point (death or any other point of interest) as a product of the baseline hazard and the exponential expression of the linear sum of $\beta_i X_i$ summed over the $p$ predictor variables.

**Reporting heterogeneity** – synonymous with interpersonal incomparability, it refers to the difference in reporting style or behavior when individuals use different response category cut-points to answer questions that relate to an unobserved latent continuous variable on a manifest categorical response scale.

**Response consistency** – is the assumption that respondents use the same response category cut-points when evaluating themselves and when evaluating the vignette characters.

**Root Mean Square Error of Approximation (RMSEA)** – is an absolute measure of fit based on the non-centrality parameter. It is commonly used for assessing fit of structural equation models or confirmatory factor analysis. It is computed as $\sqrt{\frac{\chi^2 - df}{N - df}}$, where $N$ is the sample size and $df$ is the degrees of freedom. If $\chi^2$ is less than the $df$, then it is reset to zero. The measure is positively biased i.e. it tends to be too large and the amount of bias depends primarily on the smallness of the $df$ as well as sample size. RMSEA values closer to zero indicate a closer model fit with values more than 0.1 indicating a poor model fit.

**Self-rated health** – refers to a survey technique where respondents assess different aspects of their own health by answering a single global health question “e.g. in general, how do you rate your health today?” or a series of questions “e.g. in the last 30 days, how much difficulty you had with moving around?; how much difficulty you had with feeling sad?” etc. that are typically structured on a Likert scale.
Small area estimation – refers to a variety of statistical techniques that are used to derive estimates of parameters for small sub-population areas that may or may not be part of the larger survey. Small area may refer to a small geographic area such as a district or to a small domain such as a demographic within an area.

Social cohesion – has been variably described as the capacity of society to ensure the well-being, minimize disparities and avoid marginalization of its members. It refers to the extent of connectedness and bonding amongst individuals and groups in society. It is marked by mutual moral support and trust which allows an individual to share the collective energy and resources when his own support is exhausted.

Social networking – is the term used to describe the network of social structure that includes social actors and their dyadic ties and interactions.

Structural Equation Model – refers to a model made of more than one structural equation that describe causal relations among latent variables and include coefficients for endogenous variables.

Vignette equivalence – is the assumption that different respondents interpret the same vignette in the same way.
Summary in Swedish

Sammanfattning

Bakgrund
Merparten av äldreforskningen har bedrivits i västvärlden. Forskningen om äldrande i Indien har fokuserat på sjukdomstillstånd och riskfaktorer. Kunskapen om äldres hälsa, fysisk prestationsförmåga och funktionshinder för att förstå psykosociala eller beteenderelaterade riskfaktorer är begränsad i Indien. Självsattad hälsa (SRH) har ofta använts i undersökningar för att snabbt bedöma hälsotillstånd och har även visat sig kunna förutsäga framtida sjuklighet och dödlighet. Den första vågen av SAGE-studien om globalt äldrande och vuxenhälsa ger en möjlighet att analysera de komplexa sambanden mellan åldrandets olika livsområden som hälsa, funktionshinder, kognition, dagliga aktiviteter, arbete, familj, trygghet och välbefinnande i låg- och medelinkomstområden.

Syfte
Målet med forskningen är att (a) förstå vägar genom vilka den sociala miljön, funktionshinder, hälsobeteenden och kronisk sjukdom påverkar den självsattade hälsan SRH, (b) undersöka betydelsen av SRH för att förutsäga dödlighet, (c) validera den inter-individuella jämförbarheten hos måttet, och (d) bedöma hur väl uppskattningar av SRH baserade på ett "litet område" i en demografisk longitudinell hälsoundersökning (HDSS) representerar ett större område.

Metoder
**Resultat**


**Slutsats**

Denna forskning ger stöd för värdet och nyttan av SRH som ett enkelt mått på hälsa och som prediktor för dödlighet i en åldrande befolkning. Det kan användas vid utformning av program och i politiska underlag för en gynnsam social miljö på viktiga livsområden för hälsa och välbefinnande. Det finns behov av att identifiera och justera självskattade svar för ökad jämförbarhet mellan individer och grupper. Forskningen belyser också möjligheterna att använda informationen från stora nationella undersökningar på distriktsnivå för planering och utvärdering. Slutligen diskuteras möjligheterna att integrera SRH och relaterade frågor i pågående HDSS-kartläggningar.

**Nyckelord**

Självskattad hälsa, livskvalitet, dödlighet, funktionshinder, rapporterings- heterogenitet, vinjettmetodik, åldrande, Indien.
Summary in Hindi

संक्षिप्त विवरण

पृथ्विभूषण
बुधवार या बढ़ती उम्र से संबंधित ज्यादातर शोध कार्य विकसित देशों में किया गया है। भारत में बढ़ती उम्र संबंधी अध्ययन मुख्यः बीमारी और उसके जोखिम के पहलुओं पर केंद्रित रहे हैं। भारत में बुनियादी के स्वास्थ्य, उनकी शारीरिक क्षमताओं और अक्षमताओं के आधार पर उनके मनोसामाजिक या सामाजिक व्यवहार से जुड़े जोखिम की समझ काफी सीमित रही है। अक्सर सर्वेक्षणों में लोगों के स्वास्थ्य के स्तर-आकलन (एस.आर.एच.) के आधार पर उनके स्वास्थ्य स्तर के अनुमान लगाए जाते रहे हैं और इसीं अनुमानों का उपयोग करके बीमारी और मृत्यु की समावेश एवं अंकड़े दिए जाते रहे हैं।

बुनियादी और व्यवसाय के स्वास्थ्य पर भूमिकावादी अध्ययन सर्वेक्षण (सेज) की पहल द्वारा एक अर्थात् अवसर मिला है कि एस.आर.एच. जैसी जटिल अध्यापन को बढ़ती उम्र के विभिन्न पहलुओं, जैसे स्वास्थ्य, विकलांगता, अनुष्ठान, रोज़मर्रा के कामों, व्यवसाय, परिवार, सुरक्षा और कल्याण के संदर्भ में समझा जाए।

उद्देश्य
इस अध्ययन का उद्देश्य है, (क) यह समझना कि सामाजिक वातावरण, अपने रोज़मर्रा के काम करने की अक्षमता, स्वास्थ्य व्यवहार और पुरानी बीमारियों के अनुभव किस प्रकार एस.आर.एच. को प्रभावित करते हैं, (ख) मृत्यु दर के पूर्वसूचना स्थापित करने में एस.आर.एच. की भूमिका का परीक्षण करना, (ग) एस.आर.एच. का संयोजन करना, जिससे कि उसके आधार पर एक व्यक्ति से दूसरे व्यक्ति के बीच तुलना की जा सके, और (घ) अध्ययन करना कि स्वास्थ्य एवं जनसाधारण निरीक्षण प्रणाली (एच.डी.एस.एस.) के अंतर्गत, एक 'छोटे क्षेत्र' से सीधे प्राप्त किए गए एस.आर.एच. अनुमानों की यदि 'बड़े खेत्र' से परोक्ष रूप से एकत्रित आंकड़ों के आधार पर एच.डी.एस.एस. वेब के 'छोटे क्षेत्र' के अनुमानों से तुलना की जाए, तो उनमें कितना अंतर होगा।

अध्ययन प्रणाली
बुध एच.डी.एस.एस. वर्ष 2002 से भारत के 22 गांवों में, 100,000 से भी अधिक प्राप्त लोगों के स्वास्थ्य और जनसाधारण रुझानों का अध्ययन कर रहा है। सेज सर्वेक्षण के संपूर्ण और संक्षिप्त संस्करणों को बुध में वर्ष 2007-09 के बीच 321 50 वर्षीय और 5432 50 वर्ष से अधिक उम्र के लोगों के बीच लागू किया गया। एक स्ट्रैटिजेशन मॉडल के प्रयोग से उन तरीकों का परीक्षण किया गया, जिनके माध्यम से सामाजिक और व्यावहारिक
पहलू एस.आर.एच. को प्रभावित करते हैं। कॉक्स प्रमाणीकरण हैजार्ड मॉडल के प्रयोग से मृत्यु दर के पूर्वनमान स्थापित करने में एस.आर.एच. की भूमिका का परीक्षण किया गया। विविधता स्थापित करने के लिए एस.आर.एच. के उपयोग का मूल्यांकन करने के लिए एंकरिंग विग्नेट्स का उपयोग किया गया। विविधता स्थापित करने के लिए स्व-मूल्यांकन जाब्बों का समायोजन हेटरोआर्किकल ऑर्डरिंग प्रोबिट मॉडल से किया गया। राष्ट्रीय सेज सर्वसंक्षेप के आंकड़ों से परोक्ष रूप से प्राप्त वबु में एस.आर.एच. की संभावना के आंकड़ों (इन्डायरेक्ट सिनथेटिक एस्टिमेट, इम्परिकल बेज एस्टिमेट, हेटरोआर्किकल बेज एस्टिमेट के प्रयोग से प्राप्त) की तुलना वबु सेज सर्वसंक्षेप के प्रत्यक्ष रूप से एकत्रित आंकड़ों से की गई, जिसके लिए विभिन्न डिज़ाइन और मॉडल आधारित तकनीकों का प्रयोग किया गया।

परिणाम
कम उम्र के व्यक्तियों के युक्ति ज्ञाना उम्र के व्यक्तियों में एस.आर.एच. आंकड़े खराब पाए गए। पुरुषों के मुकाबले, महिलाओं का अपने जीवन की गुणवत्ता का आकलन खराब था। एस.आर.एच. पर बढ़ती उम्र के प्रभावों की मध्यस्थता काम करने की आकर्षण द्वारा की गई। घटना सामाजिक – आर्थिक स्तर और जीवन के उच्च स्तर का जुड़वां बेहतर एस.आर.एच. से माना जाता है, लेकिन आंकड़ों इस मात्रा का समर्थन नहीं करते। धूमपण या तमाम के सेवन का कम—से—कम एक पुरानी बीमारी से किया गया, जिसका संबंध खराब एस.आर.एच. और खराब जीवन स्तर से किया गया। लेकिन, पुरानी बीमार और एस.आर.एच. और जीवन स्तर के जुड़वां के आंकड़े सामाजिक रूप से महत्वपूर्ण नहीं हैं। खराब/बहुत खराब एस.आर.एच., विकलांगता और जीवनसाधन की कमी वाले व्यक्तियों में मृत्यु संभावना अधिक पाई गई, जिसमें उम्र और लिंग के बीच कोई अंतर नहीं है। स्व—मूल्यांकन जाब्बों में विविधता रिपोर्टिंग के प्रबल सबूत मिले। जो उम्र, लिंग, शिक्षा और सामाजिक – आर्थिक स्तर से प्रभावित पाए गए। इस अभ्यास में 'अच्छे/बहुत अच्छे एस.आर.एच.' की मौजूदगी का अनुमान 50 प्रतिशत लगाया गया। यह प्रत्यक्ष सर्वसंक्षेप आंकड़े परोक्ष रूप से मॉडल आधारित होते क्षेत्र आकलन विधि से प्राप्त 45 प्रतिशत के अनुमान के भी काफी करीब है। लेकिन वबु के लिए इन्डायरेक्ट सिनथेटिक एस्टिमेट से प्राप्त अनुमान (23.2 प्रतिशत) प्रत्यक्ष सर्वसंक्षेप या मॉडल आधारित अनुमान के मुकाबले काफी कम है।
निष्कर्ष
इस अध्ययन के माध्यम से बढ़ती उम्र संबंधित स्वास्थ्य और मृत्यु समावेश के पूर्वानुमान लगाने के लिए एस.आर.एच. की उपयोगिता और मूल्य स्थापित होता है। इससे प्राप्त प्रमाण का उपयोग ऐसे कार्यक्रम तैयार करने के लिए किया जा सकता है, जिससे कि स्वास्थ्य और कल्याण जैसे जीवन के प्रमुख पहलुओं को ध्यान में रखते हुए, एक सक्षम सामाजिक परिवेश बनाया जा सके। यह अध्ययन जोर देता है कि स्व–मृत्युक्षण जवाबों को पहचान कर उन्हें आपस में तुलना करने के लिए समायोजित किया जाए, और उसके बाद ही दो व्यक्तियों या व्यक्तियों के समूहों के बीच तुलना की जाए। यह विशाल राष्ट्रीय सर्वेक्षणों से प्राप्त जानकारी को जिला प्रबंधकों द्वारा जिला और उप–जिला स्तरीय नीतियों और कार्यक्रमों के नियोजन व मूल्यांकन में उपयोग किये जाने की समावेश को रखावकित करता है। और अंततः, यह अध्ययन वह आधार देता है, जिससे कि एस.आर.एच. और उससे संबंधित सवालों को नियमित एच.डी.एस. एस. में शामिल किया जा सके।

प्रमुख शब्द
स्व–आकलित स्वास्थ्य, जीवन की गुणवत्व, मृत्यु दर, विकलांगता, रिपोर्टिंग में विविधता, एंडकरिंग विग्नेट्स, बढ़ती उम्र, भारत
Prologue - At life’s cross-roads

“Age is an issue of mind over matter. If you don’t mind, it does not matter”
– Mark Twain

I often pause as I do now, to wonder what brought me here today sitting in front of my laptop scratching my head for some brainy things to write (this was not easy for me as my surgery training had trained me to act, not necessarily to think!). I became a surgeon from KEM, Mumbai, one of the top medical colleges in India. I loved to cut and to stitch, I still do – maybe it is in my genes. But somehow I knew that my calling was elsewhere. My love for the unknown brought me to my first cross-road. I never trusted my mind. I followed my heart (at least I like to think I did) and left the security of my parents established medical practice, left the comforts of an urban life (though no sane person would say the megacity of Mumbai – at that time Bombay – was anything but that) to make Vadu a village in India my home and workplace. A village, where life skills were more relevant than surgical skills. A village where one had to book a trunk call from the only telephone available and then wait for an hour or more for the telephone operator to connect you – mind you, I am not that ancient, this was just before the telecom revolution of the 1990s. It was then that I decided to foray into public health. Curiously I felt ill-equipped to do so and that’s when I came across my next major cross-road. Every profession has its own ‘caste’ system – to leave surgery for public health was something unheard of. My teachers disowned me, though fortunately not my wife who shared the same crazy thoughts about the life we chose. My stint at Harvard was when I realized that I had finally found my true love (I mean aside from my wife) – public health research. That’s when I began my long innings of love and hate.

"Try to learn something about everything and everything about something"
– Thomas Huxley

The quote by Thomas Huxley aptly sums me up. My attention span is short, never more than a few years, before I become fidgety and want to move on to something new, different, that challenges my grey cells. I can never be the wise man in the white coat who peers down his microscope looking at the same organism for a whole of a life-time (the man’s lifetime, not the organisms’). So has my research interests changed from child health to women’s health to adult health and aging keeping in synchrony with my own life stages. It is just a
coincidence that these changes were also timed with the shifting global research agenda. As an unwritten rule, I love going back to the classroom – every 10 years – not as a teacher but as a student. Maybe it’s the nostalgia, whatever. Which brings me to Umeå – a wonderful place to study except of course, the minus 20 degree outside temperature!

Where will I go from here? – I do not yet know. Where will I wish to go? – that I do know (but that is a reflection for the next thesis!). In my culture, a person ideally goes through four stages (ashrams) of life; *bramhacharya* (celibate student life), *grihastha* (materialistic household life), *vanaprashta* (going into the forest to introspect) and *sanyasa* (going to the mountains after renouncing all that you possess) before he attains the very purpose of his life - ‘*moksha*’ the convergence of his soul ‘*atma*’ with god ‘*parmatma*’. I have struggled through mine too (though with some minor life protocol deviations). My *bramhachari* stage has been quite prolonged – it appeared never ending at times; in my *grihastha* stage I was never really materialistic except of course I had to have a good Internet connection; I often venture into the forest to introspect but have never done it seriously; the last stage of life is something I will probably only dream about.

Which brings me to my most recent cross-road. A friend asked me a year ago “why are you doing this PhD?” Need to introspect on this profound question. True. I am quite happy with the way my career has evolved. True. People may now call me Dr Dr Siddhi. True. The PhD degree certificate may or may not improve my career prospects – I will still have to fight with my boss for a salary increase! True. In the process I may contribute to human knowledge. …blah…blah…blah…. But really, the reason is quite simple yet complex like the response to the question of my research thesis ‘in general, how do you feel today?” It’s the same answer which I give to my friends when they ask me “why do I climb mountains?” – Because they are there! Because I enjoy doing so.
Chapter 1: Introduction

An aging world – the silent revolution

The ‘grey ing’ of the human population is no longer a ‘first world’ phenomenon. Rapid increases in life expectancy especially in the older age groups accompanied by a decline in mortality and especially an accelerated decline in fertility have ushered in unprecedented rates of aging. The elderly are not only the fastest growing population group but also the poorest. The elder majority are also women. Most of the population growth has taken place in Asia with India, and China contributing a significant proportion of this growing elderly population [1]. This trend is expected to continue into the first half of the 21st century. The Madrid International Plan of Action on Aging 2002 aims to mainstream aging into the global development agenda [2]. It is for the first time that governments agreed to link questions of aging to frameworks for social and economic development and human rights that were agreed upon in the past decade. Yet, a decade later, concerns of aging and the elderly suffer lack of sustained attention and resources and the political visibility needed to ensure mainstreaming aging into the global and national developmental agenda.

India’s population passed the one billion mark at the turn of the century and now accounts for 17% of the world’s population. Its population increased from 439 million in 1961 to more than 1.2 billion in 2011 (Table 1) and currently one out of every six persons lives in India. All the major forces driving demographic transition viz. a declining mortality and fertility trend, and increasing life expectancy indicate that India is clearly poised to enter the final stages of its demographic transition. There has already been a substantial decline in mortality compared to fertility. A faster decline in fertility compared to mortality is expected in the near future as mortality is already at a very low level. Total fertility rate has declined from 5.8 children in 1961 to 2.7 in 2011 and is expected to reach the replacement level of 2.1 by the next census in 2021. An Indian born in 1961 could have expected to live till the age of 43 years; today the life expectancy at birth has increased to 65 years and is projected to further increase to 70 years by 2025 [3]. The aging process in India is expected to be faster than any other developing countries.
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<tbody>
<tr>
<td>Total population (millions)</td>
<td>439.2</td>
<td>548.2</td>
<td>683.3</td>
<td>846.4</td>
<td>1028.7</td>
<td>1210.2</td>
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<tr>
<td>Population &gt; 60 years (millions)</td>
<td>25.0</td>
<td>33.0</td>
<td>43.0</td>
<td>57.0</td>
<td>77.0</td>
<td>93.2*</td>
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<tr>
<td>Population &gt; 60 years (%)</td>
<td>5.7</td>
<td>6.0</td>
<td>6.3</td>
<td>6.7</td>
<td>7.5</td>
<td>7.7*</td>
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<tr>
<td>Decadal growth in population (%)</td>
<td>NA</td>
<td>24.8</td>
<td>24.6</td>
<td>23.9</td>
<td>21.5</td>
<td>17.6</td>
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<td>Decadal growth (%) among &gt;60 years</td>
<td>NA</td>
<td>32.0</td>
<td>30.3</td>
<td>32.6</td>
<td>35.1</td>
<td>28.8*</td>
</tr>
<tr>
<td>Old age dependency ratio (per 100 persons in working age (20-64y))</td>
<td>6.4</td>
<td>NA</td>
<td>7.6</td>
<td>NA</td>
<td>8.3</td>
<td>9.0*</td>
</tr>
<tr>
<td>Crude literacy per 100 persons</td>
<td>24.0</td>
<td>29.5</td>
<td>36.2</td>
<td>42.8</td>
<td>54.5</td>
<td>64.3</td>
</tr>
<tr>
<td>Life expectancy at birth (in years)</td>
<td>43.1</td>
<td>49.8</td>
<td>55.7</td>
<td>58.6</td>
<td>62.0</td>
<td>65.1*</td>
</tr>
<tr>
<td>Life expectancy at age 60 years (in years)</td>
<td>NA</td>
<td>13.4</td>
<td>14.6</td>
<td>15.3</td>
<td>15.7</td>
<td>NA</td>
</tr>
<tr>
<td>Total fertility rate</td>
<td>5.8</td>
<td>5.2</td>
<td>4.5</td>
<td>3.7</td>
<td>3.0</td>
<td>2.7*</td>
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<tr>
<td>Infant mortality rate (per 1000 live births)</td>
<td>140.1</td>
<td>118.0</td>
<td>95.0</td>
<td>76.4</td>
<td>60.7</td>
<td>52.9*</td>
</tr>
</tbody>
</table>

* Figures for 2011 are provisional released by the Census India. Figures indicated with * are projected estimates.

(Source: Census of India 2011; World Population Prospects: The 2010, volume II: demographic profiles, UN Department of Economics and Social Affairs/Population Division [3])

The size of India’s elderly population aged 60 years and above has shown a steady increase from 25 million in 1961 to more than 93 million in 2011 – a four-fold increase in the last 50 years. With current trends, the population above 60 years age is projected to triple to about 300 million by 2050 [4]. The proportion of population in this age group has steadily increased from 5.7% to 7.7% during the same period and is projected to increase rapidly to about 17% by 2050. The percentage decadal growth amongst India’s elderly has been consistently higher than the overall population growth in the last few decades – 32% in 1971, 30.3% in 1981, 32.6% in 1991, 35.1% in 2001 and a projected 28.8% in 2011 compared to the overall population decadal growth that has in fact shown a declining trend
(24.8% in 1971 to 17.6% in 2011 - the sharpest fall of 3.9 percentage points seen in the last decade (2001-2011)) during this period. India is set to alter its status from that of a young population to an aging population by 2030.

**Population aging – a concern?**

Population aging is a subject of growing concern for public health and policy especially in less developed countries which have a higher burden of the world’s elderly population in absolute terms, than that in developed countries. Yet the less developed countries may not have the policies and infrastructure in place to address the growing needs of their aging population [5-7]. An aging population throws up both opportunities and challenges. India has one of the highest socio-demographic heterogeneities both at the regional and state levels. As more people enter the workforce and fewer children are born, there is an opportunity for economic growth. Whether India has the policies and infrastructure in place to translate this opportunity into economic growth can be debated. The challenges are many – a large educational deficit, demographic and economic disparities, unemployment and under-employment, social turbulence, political instability, global economic recession amongst others. An increasing old-age dependency ratio (number of persons aged 65 years and above per 100 persons aged 20-64 years) – 6.4 in 1961, 9.0 in 2011 – is likely to put increasing pressure on infrastructure and familial and non-familial incomes. As populations age, India’s elderly population faces the dual and increasing burden of chronic non-communicable and degenerative diseases and existing or emerging communicable diseases that will require new investments in health infrastructure and security systems in an already overburdened health system [8]. It is estimated that less than 5% of all Indians are covered under any form of health insurance [9]. The majority of India’s elderly are outside the social safety nets, more than 90% face economic insecurity as they are not covered by pension schemes, and are forced to participate in the labor force predominantly in agriculture in rural areas [10]. India is already experiencing the collateral effects of demographic transition and a growing economy in terms of breakdown of traditional familial, social networks and societal support systems and structures that put to risk the social, financial and emotional securities of its elderly population [11, 12]. Providing social, income and health securities with weak social and health security systems in place are some of the daunting challenges faced by India and other less developed countries [13].
Aging research – a growing need of developing countries?

Aging research has largely been in the realm of demographers and economists. There is a large body of literature mostly from the developed countries that has focused on the living arrangements of the elderly including living alone, with spouse or with children [14, 15], the determinants leading to a specific living arrangement [16-26], marital status, place of residence, kinship, and life satisfaction in the elderly [27-31]. There also exists an equal if not larger body of literature on the health status of the elderly though this is mainly focused on risk factors, disease and disability - both physical and mental - arising from obesity, senility, and other age-related degenerative conditions [32-44]. Evidence on physical performance and disability is limited to understanding the psychosocial and behavioral risk factors [45-47]. The effects of widowhood [48-52], poverty on the basic needs (food, clothing, health) of the elderly [53-55], old age dependency [56-58] and health care utilization [59-61] have also been well studied as has the gender differential in longevity [62-65].

Until recently, a major drawback in aging research has been the lack of a global data infrastructure that could simultaneously address all the important life domains of the elderly – work history, economic, social and emotional securities, health behaviors, life satisfaction, quality of life, subjective well-being, ability to perform activities of daily life, physical performance, cognitive ability, disease, disability, and health care utilization – on a common platform. Anticipating such a need, the National Institute of Aging (NIA) initiated the Health Retirement Study (HRS) in the USA, a longitudinal study that has followed up a cohort of adults aged 50 years and above every two years since 1992, focused on multiple inter-linked life domains – income and wealth, health and use of health services, work and retirement, and family connections. The HRS has become a model for a growing network of harmonized longitudinal aging studies around the world – the Mexican Health and Aging Study (MHA), the Irish Longitudinal Study of Aging (TILDA), fifteen countries in the Study of Health, Retirement and Aging in Europe (SHARE), the Indonesian Family Life Survey (IFLS), the Korean Longitudinal Study of Aging (KLoSA), the Chinese Health and Retirement Longitudinal Study (CHARLS), the Survey of Health, Aging and Retirement in Thailand (HART), the Japanese Study on Aging and Retirement (JSTAR) and the Longitudinal Aging Study in India (LASI). The Study on global AGEing and adult health (SAGE) on which this research is based, is
yet another initiative to build a global database on aging in low- and middle-income countries that is harmonized with other similar efforts.

**In general, how would you rate your health today?**

Self-Rated Health (SRH) is a complex latent construct commonly used to assess health and well-being [66-69]. It is a useful all-inclusive measure that substitutes for other more specific measures of health and disability in predicting health outcomes [70]. It is known to predict health care expenditure and physician use [71, 72], risk for premature mortality [73, 74] and morbidity [75], and prognosis of survival and physical disability in the elderly [76-78]. The role of SRH in evaluating and understanding the complexities of community interventions has been studied [79]. It is a reliable measure based on a simple to ask global health question “*In general, how would you rate your health today?*” [80]. Such a cost-effective measure has immense practical utility in routine health care and health research as a supplement or substitute to other more expensive and invasive health measures especially in resource scarce settings. The person is asked to choose one discrete response from a categorical scale that may range from very good, good, moderate, bad and very bad. Though the exact wordings and response options may vary with different surveys, which make it difficult to directly compare distributions and levels of measurements across surveys, SRH assesses essentially the same phenomenon across different settings [81].

**Understanding self-rated health – theoretical frameworks**

Several theoretical frameworks have been developed in social epidemiology to explain ill-health [82]. The Hertzman et al. theory of cumulative advantage/disadvantage (Figure 1) presents a more general framework for the determinants of adult health that combines a life course perspective and the contemporary circumstances that influence health and SRH in adult life and older ages.
The three levels of social aggregation in the form of a bull’s-eye represent the contemporary circumstances, while the arrow from birth to death represents the latency, pathway and cumulative effects from a life course perspective. The framework postulates that the environment in early life may influence health outcomes at later life through three processes. First, early life events may affect health outcomes in later life, independent of the experiences in the intervening period. An example of this latency effect is Barker’s hypothesis of fetal and early life origins of adult onset cardiovascular and other chronic conditions [84]. Second, events in early life set persons onto different life courses (pathway effect) that in turn affect health states over time. To illustrate the pathway effect, Hertzman gives the example of how stimulation, stability and security in early childhood affect the child’s preparedness for schooling that in turn affects the risk of behavioral problems and failure at school, which in turn affects the mental well-being in early adulthood. The parent’s social status determines the community in which the child spends his early life, which in turn influences the life chances and social opportunities available to the child as s/he grows up into adulthood. In practice, it is often difficult to tease out latency effect from pathway effect. The third process links the accumulation of advantage or disadvantage over time to cause a dose-response effect in later life. An example is the cumulative effect of income suggested by a stronger
association with mortality for earnings over several years than for single-year earnings [85]. However, the major focus of the Hertzman framework is on contemporary determinants of health organized at three levels of social aggregation. At the ‘macro’ level, the national socioeconomic environment (per capita income, equity of income distribution etc.) determines health [86]. At the ‘meso’ societal level are factors such as social trust, social cohesion and social affiliation [87] while at the ‘micro’ level are the person’s access to social support, availability of informal help, kinship and intimate relationships [88]. This framework is illustrative of one of the many possible pathways of health or ill health but is limited by its focus on the socioeconomic characteristics (social networking at the individual level) as it does not consider the influence of biological, genetic and other factors. Moreover, it is unclear how well this and other similar frameworks that consider only an individual’s recent and/or past experiences of health and not his expectations of health, would explain possible pathways to and from SRH.

In contrast, Jylha’s theoretical framework (Figure 2) proposes that a person chooses a self-rating response to the global health question by a cognitive process that is inherently subjective as well as contextual – the physiological, biological and emotive experiences of the person influenced by the contextual environment [89]. SRH is influenced not only by perception, experience of disease and ability to perform activities of daily living but also by health expectations that in turn are influenced by a person’s psychosocial and cultural contexts. The framework suggests that a person recognizes in his own way the ‘meaning of health’; identifies the different components of ‘my health’ based on ability to function physically, body feelings, pain and sensations, signs of disease, diagnosed health problems, health behaviors, perceived risks and threats to future health; then processes this ‘information’ in the context of his age, earlier health experience, health state of his peers and his own health expectations. He then summarizes this mass of information into a single discrete response on a categorical scale based on his understanding of the scale, his emotions at the time, and cultural conventions and norms of reporting health states.
INTRODUCTION

"How is your health in general? Is it excellent, very good, good, fair or poor?"

Figure 2: Theoretical framework for SRH. (Source: Jylha 2009 [89])
Self-rated health – determinants and pathways

SRH, though non-specific in its measurement, is a surprisingly reliable measure that is sensitive to a person’s perception of his health and it complements other more specific measures of health. However, relying on it solely may be misleading [90]. SRH is known to worsen as age advances and women are more likely than men to report poor SRH [91-93]. The association of aging with SRH is possibly mediated through functional disability and disease [94-96]. Limitations in functional ability – sleep, ability to perform activities of daily living, mobility and cognition – are strongly associated with poor SRH [97-101]. Physical functioning has a stronger association with SRH than mental or social functioning. Furthermore, the association between mental or social functioning and SRH differs amongst persons who are depressed or cognitively impaired [102].

Globally, there is a large body of literature on the psychosocial and socioeconomic determinants of SRH. However the pathways through which they influence SRH are unclear. Health can affect the ability to work and earn. The socioeconomic environment shapes perception of health [103, 104]. Widowhood is strongly associated with poor SRH for both men and women, independent of socioeconomic status [105]. Persons with no education report higher levels of illness and poor SRH independent of age [106-108]. Material deprivation and poor financial security is related to poor SRH [109, 110]. The predictive role of social experience on SRH is less clear [90]. Family cohesion, number and type of kin ties, marital stability, and social trust are associated with SRH [111-113]. This association is however weaker when controlled for economic status [114] and it is also influenced by functional abilities in mobility and inter-personal relationships [94]. Visiting friends, attending social and religious events, volunteering in community activities and diversity of participation in various social and community events are all positively related to SRH, independent of age and gender [115-118].

Healthy behaviors and absence of chronic illness (diabetes, depression, etc.) predict ability to perform activities of daily living and contribute to good SRH in old age [93,112,119-125]. A physically active lifestyle in midlife is critical for maintaining high physical function in old age, notwithstanding any long-standing illness [126]. Obesity strongly predicts limitation of mobility and a large number of chronic illnesses predict poor SRH outcomes [127, 128].
Self-rated health – does it predict mortality?

A strong association between poor SRH and risk of all-cause and disease specific mortality, independent of age, sex, income, education, social networking, health behaviors and chronic disease is consistently reported from Europe and North America [74, 129-135]. Similar associations are seen in Asia [136-139]. A meta-analysis of 22 studies shows a two-fold increase in all-cause mortality for persons who report poor SRH [140]. SRH is a strong predictor of mortality across all socioeconomic strata. The effect of SRH on death is stronger in higher socioeconomic groups because of the lower base mortality in these groups [141]. However, the predictive ability of SRH for mortality may be culturally sensitive and cross-cultural comparisons must be made with caution [142]. The pathways through which SRH predicts mortality are unclear though there is some evidence from high-income countries that high levels of disability, illness and poor physical and cognitive function may influence this association [143]. Disability and disease may affect body function, ability to perform activities of daily living and social networking that in turn may affect SRH and mortality [144]. It is not known to what extent disability and social factors mediate the predictive power of SRH on mortality. The role of SRH as an effect modifier – whether it strengthens or weakens the impact of more established risk factors on outcomes of morbidity and mortality - has been studied in high-income countries [141, 145]. Due to lack of infrastructure for conducting longitudinal studies, unreliable mortality and cause of death information, very few studies have linked SRH to mortality in low- and middle- income countries [136, 146-148].

Self-rated health – the problem of reporting heterogeneity

An inherent problem with self-rating long overlooked by social scientists is the concern of interpersonal incomparability. When a person is asked to rate a trait of interest with a discrete response on an ordinal scale, the response is analyzed with the assumption that it represents a measure of an underlying latent interval scale. The person uses some thresholds that are unknown to the researcher to categorize his discrete response. For such analysis, the tendency is to assume that all persons understand the response categories in the same way i.e. all persons use the same thresholds on the underlying latent interval scale which differentiate the categories ‘very good’, ‘good’, ‘moderate’, ‘poor’ and ‘very poor’ on the manifest scale. However there is a large body of evidence to suggest that individuals
and groups interpret and choose response categories very differently. Two individuals or groups of individuals with identical health levels may rate their own health differently based on their understanding, expectation and experience of their own health as is illustrated by Jylha (Figure 2) [89]. This difference in reporting behavior is referred to as response category differential item functioning (DIF) [149] or reporting heterogeneity [150]. Reporting heterogeneity has been identified across sexes [151], socioeconomic strata [152], race and ethnicities [153, 154], and countries [155-158]. Unless recognized and corrected for, reporting heterogeneity can lead to misleading and incorrect interpretations [159].

Figure 3: An example illustrative of reporting heterogeneity in self-rated health response. $H_{H}^{*}$ and $H_{L}^{*}$ indicates true health level of high and low educated individual (Source: Bago D’Uva, 2008 [160])

Figure 3 illustrates the problem of reporting heterogeneity in two persons with different levels of education. In the example we assume the true health level of the higher educated person ($H_{H}^{*}$) to be higher
than that of the person with lower education ($H^L_L$) as shown by the solid horizontal lines intersecting the right vertical line depicting the latent health scale. Despite the difference in their true health levels, both persons choose the ‘moderate’ health response category on the manifest scale. This is because the lower educated person has lower thresholds for categorizing his health than the higher educated persons. As we do not have information on the thresholds, we would incorrectly conclude that there was no difference in the true health levels of the higher and lower educated persons if based solely on the reported response.

Anchoring vignettes is a strategy used in recent years to identify and overcome this problem of reporting heterogeneity in survey rating responses [161, 162]. Anchoring vignettes describe a fixed level of the trait of interest in a hypothetical character. The individual is then asked to rate the level of trait for the vignette character on the same scale as he would do for his own. Typically several vignettes representing various levels of the trait are administered to each person. In the same example (Figure 3), five vignettes, each depicting a fixed level of health are administered to both persons. The higher educated person ($H^H_H$) rates the first vignette as ‘good’ compared to the ‘very good’ rating by the lower educated person ($H^L_L$) for the same fixed level of health revealing reporting heterogeneity due to differences in the use of response category thresholds by the two persons. Similarly vignettes 2 to 5 provide additional information on the variation in the vignette ratings between the two persons along the health spectrum. In other words, vignettes are used to identify the threshold locations on the latent scale that persons use to choose response categories. The differences in threshold locations are then adjusted for statistically to allow the self-rating responses to be compared between individuals, unbiased by reporting heterogeneity. It must be noted that anchoring vignettes can identify, and correct for reporting heterogeneity. However they do not explain ‘why’ there are such differences in the first place. In the above example, the reporting bias may arise if higher educated persons are better aware of, and have better access to treatment options and so are less tolerant of poor health and set higher standards or thresholds for good health than lower educated persons. But there can be a bias in the opposite direction if higher educated persons also are high income earners and hence believe that they should be having better health and hence are more tolerant or use lenient standards or lower thresholds for reporting good health [163, 164].
Anchoring vignettes has increasingly been used in the last decade to improve interpersonal and cross-cultural comparability of survey responses in the areas of political efficacy, work disability, job satisfaction, life satisfaction, health and health system responsiveness [149, 160, 165-169]. However the use of anchoring vignettes to identify and correct for reporting heterogeneity requires two critical assumptions – response consistency and vignette equivalence. Response consistency assumes that the individual uses the same thresholds to rate the vignette as for rating self. Vignette equivalence assumes that all individuals understand the fixed level of trait depicted by the vignette in the same way. Earlier studies have looked at inconsistent ordering of vignette severity levels as informal checks for these assumptions [168]. Recent advances in the analysis of anchoring vignettes now allow a more rigorous evaluation of the assumptions using parametric methods [169-171].

**Self-rated health – small area large area comparisons**

Large national surveys, though rich in information, lack adequate precision at the small area level and are of limited value for district or sub-district level planning and resource allocation [172, 173]. On the other hand, information from small area surveys including that from Health and Demographic Surveillance Systems (HDSS) is useful for planning at the micro-level but is critiqued often without justification for its lack of representativeness at the national or sub-national level. There are few studies that test the generalizability of information from micro-level HDSS to the national or sub-national level [174]. Small area estimation procedures are simple design-based or complex model-based techniques that allow robust estimates to be derived for small areas from large area information. The estimates borrow strength from other similar small areas thus effectively increasing the sample size of the small area. These values are combined into the estimation process through a model which links the related small areas using auxiliary information, most often census information that is available at the small area level [175]. Many of the small area estimation techniques have been pioneered in the United States [176-178] and more recently in the UK [179-181] and aim to improve on the robustness of the estimator and prediction error. A number of studies have applied small area estimation methods to estimate disease counts including prevalence of diabetes [182], heart disease and stroke [183], psychiatric illness [184, 185], asthma [186], chlamydial infection [187], dental caries [188], rare outcomes like birth defects [189], and disability [190] at the county or small area level. Small area
estimation methods have been used to estimate risky health behaviors such as smoking [191, 192], alcohol use [193] and obesity [194-196] and prioritize communities with high under-fives mortality rates [197] and breast cancer [198] for targeted health interventions. Other studies have applied small area estimation techniques to estimate the unmet need for contraceptive use [199], institutional births [200] and monitoring vaccination coverage [201, 202]. Small area estimation methods have been used to understand geographical disparities in disease [203, 204], income inequity, poverty [205], the ecological relationship between inequity and illness [206], health insurance coverage [207, 208] and homelessness [209]. The place and neighbourhood effect on SRH is well studied [210-213]. A review of 39 studies reveals that less favourable small area level socioeconomic conditions are associated with poorer SRH [214]. Area level affluence, positive perception of area environment, social capital, favourable opportunity structures and social functioning are predictive of better SRH [215-217]. Several studies suggest significant mediating effects of the area level social environment between area inequality and SRH [218-220]. There are no studies that compare the small area estimates for SRH prevalence derived from large area surveys with direct survey estimates of a small area.

The current PhD research work

Scope

The potential of SRH as a measure of health and predictor of health outcomes in the context of aging is not fully explored. Figure 4 defines the scope of this PhD research. It brings together on the same platform, research on SRH and the aging process in its various key life domains of health, disability, cognition, activities of daily life, work, family, security and well-being. It follows the theoretical framework that SRH is consequent to the interplay of an individual’s experience and expectation of his bodily function and feelings, and environment [89]. However, the scope of this research is limited by the purpose of the original SAGE survey for which the data was collected. It is structured around four distinct yet inter-linked research papers centred on SRH.
The work undertaken is an effort to use newer improved statistical approaches to address specific research questions (rephrased as specific objectives below) that are dealt with in-depth in four peer-reviewed or under-review scientific papers. The first research paper titled “Unpacking self-rated health and quality of life in older adults and elderly in India: a Structural Equation Modeling approach” explores the pathways through which the social environment, functional disability, health behaviour and chronic disease experience directly influence SRH, as well as mediate the influence of age and sex on SRH. It tests an evidence-based theory using a structured equations modelling (SEM) approach. The second research paper titled “Does self-rated health predict death in adults aged 50 years and above in India? Evidence from a rural population under health and demographic surveillance” builds further on, to examine the role of SRH and the influence of disability and other factors in predicting mortality using a Cox Proportional Hazard modelling approach. The third paper titled “Evaluating reporting heterogeneity in self-reporting health responses amongst adults aged 50 years and above in India – an anchoring vignettes analytic approach” addresses the methodological concern of interpersonal incomparability in self-
rating responses of health. It uses information from anchoring vignettes to identify and adjust SRH responses for reporting heterogeneity in two distinctive functional domains of mobility and cognition. This paper uses the hierarchical ordered probit modelling (HOPIT) approach. The fourth paper titled “Self-rated health: small area large area comparisons amongst older adults at the state, district and sub-district level in India” addresses the methodological issue of small area – large area comparisons. It uses different model-based small area estimation techniques (using both frequentist and Bayesian approaches) to see how well small area estimates of SRH prevalence derived from large area surveys, compared with small area estimates derived directly from small area surveys. It addresses the issue of how well information from a micro-level HDSS area can represent or be generalized to a larger national or sub-national level.

Aims

The overall aim is to fill critical gaps in knowledge of SRH in the context of aging in a rural elderly population in India. The goal is to validate and integrate its use as a simple valid measure of health and well-being in the aging context into routine HDSS.

Specifically, the research aims

- to understand pathways through which the social environment, functional disability, health behaviours and chronic disease experience and other factors influence SRH (paper 1)
- to examine the role of SRH and the influence of disability and other factors in predicting mortality (paper 2)
- to validate SRH to improve its inter-personal comparability (paper 3)
- to assess how well estimates of SRH derived directly from a ‘small area’ survey in a HDSS site compares with ‘small area’ estimates for the HDSS site derived indirectly from a ‘large area’ survey (paper 4)
Chapter 2: Methods

The setting

The study area is situated in rural Pune district in Maharashtra State which is one of the more progressive states of India (Figure 5). It is a rural area situated about 40 km from the metropolis of Pune. A major national highway passes through the area. Three villages situated along this highway fall within an industrial zone and have seen rapid semi-urbanization and high levels of in-migration of low-skilled workers from other parts of the state. Villages situated away from the highway retain their rural ambience with farming (mainly cash crops such as sugarcane) as the main source of income. The health infrastructure is typical of other such rural areas situated in proximity to large cities and towns. Apart from a rural hospital, there are more than thirty small hospitals (bed strength ranges from five to fifteen) in the private sector, which is largely unregulated.

Figure 5: Vadu Demographic Surveillance Area situated in Pune district, India. (Source: Vadu HDSS, KEM Hospital Research Center, Pune)
The Vadu Rural Health Program

The Vadu Rural Health Program, initiated in the late 1970s is part of a 3-tier health care model. The first tier is the outreach program, a unique example of public-private partnership between King Edward Memorial (KEM) Hospital, Pune and the District Health Services that provides primary health care for a geographically well-defined population of about 100,000 individuals residing in 22 villages. At the second tier is the Shirdi Saibaba Hospital situated in Vadu village, which is a 35 bed multi-disciplinary rural hospital that provides secondary level medical care to its population. The parent institution, the 550-bed KEM Hospital situated in nearby Pune city provides the third tier of tertiary level care.
The Vadu Rural Health Program has a long and rich legacy of clinical trials, intervention studies, disease burden studies, and social science research in public health. The research portfolio is diversified and includes maternal and child health, women’s health, communicable diseases (measles, influenza), and non-communicable diseases. Vadu is currently developing a platform for adult health and aging research. Prior to the SAGE survey, it participated in the INDEPTH – WHO collaboration on Non-Communicable Diseases (NCD) Risk Factor surveillance using the WHO STEPwise approach in 2003 amongst adults 25 years above [221]. A 1993 birth cohort that studied the effects of maternal nutrition on fetal growth and low birth weight is being followed with biomarkers for late onset type-2 diabetes using a life course perspective.

The Vadu HDSS is an independent system initiated in 2002 to monitor health trends, disease and vital events in the population served by the Vadu Rural Health Program. The surveillance system allocates a unique permanent identifier for each person residing in the 22 villages. A baseline was established in 2002. A household census conducted every six months enumerates all births, deaths and migrations. A verbal autopsy is conducted for all deaths that are then assigned a cause and ICD-10 code. The HDSS database complements hypothesis driven research by providing socio-demographic information at the individual and household level that may be relevant to address specific research questions. The HDSS database links all research studies implemented in the Vadu HDSS through its unique identifier and provide a platform for aging research using a life course perspective.

**Study on global AGEing and adult health**

As a follow up to the World Health Survey conducted in 70 countries in 2002, the World Health Organization (WHO) initiated the Study on global AGEing and adult health (SAGE) in six countries – Russian Federation, China, Ghana, Mexico, South Africa and India in 2007 (Figure 6).
Figure 6: World map showing WHO-SAGE and INDEPTH-SAGE study sites, by collaborating country. (Source: INDEPTH Network, Accra)

**SAGE – the full version**

The WHO SAGE is a longitudinal study with nationally representative samples of adults aged 50 years and above with comparison samples of younger adults (18-49 years age) in each country [222]. It aims to generate valid and reliable information on a range of health and well-being outcomes and the aging process from countries in different stages of the demographic transition (Ghana, South Africa, Mexico, and Russian Federation) as well as the two most populous countries India and China. The WHO SAGE is comparable to the longitudinal aging studies in high-income countries viz. HRS, SHARE and the Collaborative Research on Aging in Europe (COURAGE). The World Health Survey participants in 2002 served as the baseline cohort (Wave 0) for the six countries which are part of WHO SAGE. A sample of participants from wave 0 in four countries (Mexico, Ghana, Russia and India) and new participants from all the six countries were administered a full version of the SAGE questionnaire; anthropometry, performance and cognitive tests were performed and blood spots were taken in 2007 (Wave 1). The next follow up of participants (Wave 2) is planned in 2014.
SAGE – the short version

As part of a National Institute of Aging (NIA) supplemental grant to WHO, a short version of the SAGE survey questionnaire that focused on health and well-being was also implemented in 2007 in six HDSS field sites from the International Network for the continuous Demographic Evaluation of Populations and Their Health (INDEPTH Network) - Agincourt HDSS (South Africa), Ifakara HDSS (Tanzania), Matlab HDSS (Bangladesh), Nairobi HDSS (Kenya), Navrongo HDSS (Ghana), and Vadu HDSS (India). Two additional sites (Filabavi HDSS, Viet Nam and Purworejo HDSS, Indonesia) were supported by FAS, the Swedish Council for Health, Working Life and Welfare through the Umeå University [223, 224]. The purpose was to generate comparable information using common strategies to measure aging and adult health across HDSS sites in low- and middle-income countries and to develop methods to link and integrate routine surveillance with longitudinal survey on aging.

Additionally, the full version of the WHO SAGE survey was also implemented in a random sample of participants in Agincourt HDSS (South Africa), Navrongo HDSS (Ghana) and Vadu HDSS (India) that also had a comparable national level SAGE survey (Figure 6). The purpose was to see how well small area estimates derived from large area national surveys compared with estimates derived directly from small area surveys. In other words, how well did small area data compared with national level data.

SAGE – ethical, sampling, training, and other operational issues

The Vadu Rural Health Program implemented both the full and short version of SAGE in 2007. The SAGE survey in Vadu was approved and monitored by the WHO Ethics Review Committee and the KEM Hospital Research Center Ethics Committee. Information sheet and consent form were translated into Marathi and Hindi languages and pre-tested. Individuals participated in the study after an informed and written consent. An Ethics Committee query on the issue of collecting blood spots in the absence of dedicated funds to analyze for bio-markers was resolved by taking consent from participants that the blood spots were taken for biomarkers to be analyzed at a later date on availability of funds. We faced many ethical concerns in the field. Elderly participants would once too often share their personal and domestic grievances with our investigators who then struck a balance between providing an empathetic ‘ear’ yet keeping the focus on the
research interview. As a health care provider for our population, we were able to provide backup diagnostic, therapeutic and counseling referral services as required, for any new or existing illness reported by the individual. Another challenge was to resolve a priori, the ethical dilemma that aside from adding onto the knowledgebase, how would any of the stakeholders (the researcher, the program manager, the policy maker or the community) benefit from this research?

Simple random samples of 500 and 6000 individuals was drawn in two independent stages from a list of 9801 persons aged 50 years and above generated from the Vadu HDSS database (2006) for potential enrolment into the full and short versions of the SAGE survey respectively. Nine village based graduates (field investigators) were trained with the aid of the training manual developed by the WHO [225]. All questionnaires were adapted into the local language Marathi and pre-tested in a population outside the study area prior to the start of the survey. Study participants were interviewed by the trained field investigators under the supervision of a social scientist.

Twelve proxy respondents (usually a family member) interviewed on behalf of the selected individuals who were unable to respond for themselves were excluded from the final analysis. About 10% of the participants who were administered the full version of SAGE, were re-tested by the social scientist for quality assurance. All information was computerized using a customized Census and Survey Processing System (CSPro) data entry and management software. Consistency checks, range checks and other quality control checks were installed.
at the data entry level. The SAGE data was linked with the HDSS database to further enhance it and provide longitudinal information on events such as subsequent deaths.

The national SAGE survey in India used a multi-stage stratified clustered design to sample individuals [226]. The sample frame comprised 19 of the 28 states and seven union territories of India. The 19 states were categorized into six groups based on four indicators of infant mortality, female literacy, per capita income and safe deliveries. One state was randomly selected from each group. The sample was further stratified by urban or rural locality. Individual weights were post-stratified according to 2006 projected population estimates. For the small area large area analysis, we included only the sample from the rural strata of one of the six selected states viz. Maharashtra.

**SAGE – data collection tools**

The purpose of the SAGE survey instrument was to collect information on a broad range of self-assessments of health and well-being that was comparable across individuals and populations. The SAGE survey comprised of two main questionnaires – household and individual, and three auxiliary questionnaires viz. proxy respondent, retest, and verbal autopsy. For study participants who were unable to respond, the proxy respondents were asked only about the health state descriptions, chronic conditions and health care utilization sections on behalf of the study participant.

Table 2 summarizes the information collected in the household and individual questionnaires. The WHO-SAGE training manual provides information on methodological details of how the self-assessment of health data was collected, the response categories, how the physical performance and cognitive and lung function tests were performed, how the blood pressure and pulse were taken [225].

The short version of the SAGE survey questionnaire included only the sections on health state descriptions and the corresponding vignettes, the 12-item WHODAS-II schedule and perceptions about quality of life and well-being using the eight-item WHOQOL measure. The response to the global question on SRH “In general, how would you rate your health today?” was recorded on a five-point Likert scale where 1 indicated ‘very good’ health and 5 indicated ‘very poor’ health.
Table 2: Summary of measures included in the full version of the SAGE survey  
(adapted from source: http://www.who.int/healthinfo/sage/SAGE_Waves0_1_SummaryMeasures.pdf)

<table>
<thead>
<tr>
<th>Domain</th>
<th>Household Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household identification, contact and sampling details</td>
<td>Identification and contact details; structure of household; dwelling characteristics; improved water, sanitation and cooking facilities</td>
</tr>
<tr>
<td>Transfers and support Networks</td>
<td>Family, community and government assistance into and out of the household; informal personal care provision / receipt</td>
</tr>
<tr>
<td>Assets, income and Expenditure</td>
<td>List of household assets; sources and amount of household income; improved household expenditure on food, goods and services, health care</td>
</tr>
<tr>
<td>Household care and health insurance</td>
<td>Persons in household needing care; mandatory and voluntary health insurance coverage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Domain</th>
<th>Individual measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-demographic characteristics</td>
<td>Sex; age; marital status; education; ethnicity / background; religion; language spoken; area of residence; employment and education of parents</td>
</tr>
<tr>
<td>Work history and benefits</td>
<td>Length of time worked; reasons for not working; type of employment; mode of payment; hours worked</td>
</tr>
<tr>
<td>Health states and descriptions</td>
<td>Overall self-rated health; eight self-rated health domains (affect, mobility, sleep/energy, cognition, interpersonal activities, vision, self-care and pain; 12-item WHO Disability Assessment Schedule, Version 2 (WHODAS-II); activities of daily living (ADLs); instrumental activities of daily living (IADLs); vignettes on health state descriptions</td>
</tr>
<tr>
<td>Domain</td>
<td>Individual measures</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Anthropometrics, performance tests and biomarkers</strong></td>
<td>Measured blood pressure; self-report and measured height and weight; measured waist and hip circumference; timed walk; near and distant vision tests; grip strength, executive functioning (verbal recall, digit span forwards and backwards, verbal fluency); spirometry; non-fasting finger prick blood sample (stored at -20°C) as dried blood spots</td>
</tr>
<tr>
<td><strong>Risk factors and preventive health behaviours</strong></td>
<td>Smoking; alcohol consumption; fruit and vegetable intake; physical activity (GPAQ)</td>
</tr>
<tr>
<td><strong>Chronic conditions and health services coverage</strong></td>
<td>Self-reported and symptomatic reporting of arthritis; stroke; angina (Rose Questionnaire); asthma; and, depression (ICD-10, DSM-IV). Self-reporting of diabetes; chronic lung disease; hypertension; cataracts; oral health; injuries; cervical and breast cancer screening</td>
</tr>
<tr>
<td><strong>Health care utilization</strong></td>
<td>Past need for health care; reasons for health care or for not receiving health care; inpatient and outpatient health care: number of admissions / visits within the past 3 years (inpatient) or 1 year (outpatient); reasons for admission / visit; details of hospital or provider; costs of hospitalization or health care visit; satisfaction with treatment; health system responsiveness; vignettes for responsiveness of health services</td>
</tr>
<tr>
<td><strong>Social cohesion</strong></td>
<td>Community involvement and social networks; perceptions of other people and institutions; safety in local area; stress; interest in politics and perceptions of government</td>
</tr>
<tr>
<td><strong>Subjective well-being and quality of life</strong></td>
<td>Perceptions about quality of life and well-being; 8-item WHO Quality of Life measure (WHO-QOL); Day Reconstruction Method (DRM)</td>
</tr>
<tr>
<td><strong>Impact of caregiving</strong></td>
<td>Household members needing care; type of care required; length of time spent on care; costs of care; impact of providing care on career well-being</td>
</tr>
</tbody>
</table>
The SAGE questionnaire asked individuals to grade their ability to perform tasks in eight functional domains of health (mobility, self-care, pain, cognition, relationships, sleep, affect and vision) in the preceding 30 days. Each domain included two self-rating questions, one for a lower and another for a higher level of functional ability. The SAGE individual questionnaire was developed as four different sets (A, B, C and D) – each set was different only in terms of the health domain of the vignettes – set A included vignettes for mobility and affect; set B for pain and interpersonal relationships, set C for sleep and vision, and set D for self-care and cognition. Individuals were randomly allocated to four groups and each group was administered a vignette set comprising two domains. Following the self-reported difficulties, a total of ten vignettes in two functional domains were administered to a respondent. The vignettes for the two functional domains in a set and the severity order of the vignettes were administered in random order. The names of the hypothetical persons in the vignettes were chosen so as to be of the same sex as the respondent and be locally and culturally appropriate. Before administering the vignettes, respondents were advised to think of the hypothetical person’s experience in the vignette as if they were their own. After each vignette, the exact same questions as the two self-rating questions for the respective domain were asked replacing ‘self’ with the name of the hypothetical person in the vignette. For all assessments of self and vignette characters, the respondent was asked to rate on a five-point ordinal scale of increasing difficulty (no difficulty, mild, moderate, severe, and extreme difficulty).

We constructed three additional health measures based on limitations in functional ability and subjective well-being. The WHO Health State score was based on sixteen questions (two from each of the eight functional domains). Item response theory (IRT) in Winsteps was used to derive a Rasch summary score. The score was transformed to a scale of 0 to 100 where 0 indicated ‘best’ and 100 indicated ‘worst’ health state. The shortened version of the WHO Disability Assessment Schedule (WHO DAS-II) score was based on twelve questions that assessed six domains of functioning in daily life (understanding and communicating, getting around, self-care, getting along with others, life activities and participation in society) [227]. The weighted mean of responses to the twelve questions was transformed into a final score that ranged from 0 to 100 (where 0 indicated no disability and 100 indicated extreme disability). The WHO Quality of Life (QOL) score was based on eight questions that assessed overall happiness and satisfaction with health, living
conditions and other aspects of life. The weighted mean of responses to the eight questions was transformed into a final score that ranged from 0 to 100 (where 0 indicated best quality of life and 100 indicated worst quality of life). All the three scores were then standardized as z-scores.

The SAGE dataset was enhanced by linking it with the HDSS database for additional individual and household level socio-demographic characteristics (age, sex, marital status, education, occupation, and socioeconomic status). Age was categorized into ten-year intervals. Education was categorized as ‘primary or less’, ‘secondary’ and ‘higher secondary or more’. The presence or absence of ‘spousal support’ was determined based on the individual’s marital status and the co-residence of spouse. The socioeconomic status of all households had been assessed separately based on the Indian National Family Health Survey (NFHS) Standard of Living Index (SLI). The summary index score was calculated for each household based on a sum of weighted scores for facilities (toilet, electricity, and drinking water source) and physical assets (land and livestock ownership, material assets such as refrigerator etc.). All households were assigned to quintile groups based on the summary index score. Deaths among SAGE participants in subsequent years and cause of death information were captured from the verbal autopsy data of the HDSS. Person-years of follow-up were estimated for all participants from the date of SAGE interview until death or censoring (out-migration or last HDSS visit before the end of the follow up period on 30 June 2011).

**Statistical methods**

Table 3 summarizes the datasets and the main statistical methods used in the four research papers.

Analysis was done using statistical packages Stata v11, R, LISREL v8.8, and Win BUGS v14 as relevant. Maps were generated using Quantum GIS v1.8.0. We provide here an overview of the statistical models and why we chose them. For details of each method, the reader is referred to the papers and the appropriate references in the papers [148, 228-230].
Table 3: Overview of statistical methods used in the PhD research

<table>
<thead>
<tr>
<th></th>
<th>Paper 1</th>
<th>Paper 2</th>
<th>Paper 3</th>
<th>Paper 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title</strong></td>
<td>Unpacking self-fated health and quality of life in older adults and elderly in India: A Structural Equation Modelling approach</td>
<td>Does self-rated health predict death in adults aged 50 years and above in India? Evidence from a rural population under health and demographic surveillance</td>
<td>Evaluating reporting heterogeneity in self-rating health responses amongst adults aged 50 years and above in India – an anchoring vignettes analytic approach</td>
<td>Self-rated health: small area large area comparisons amongst older adults at the state, district and sub-district level in India</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>To understand pathways that influence SRH</td>
<td>To examine the predictive role of SRH and mortality</td>
<td>To improve inter-personal comparability of self-reported measures of health</td>
<td>To compare directly and indirectly derived small area estimates</td>
</tr>
<tr>
<td><strong>Data sets</strong></td>
<td>Full SAGE (Vadu) + HDSS (Vadu)</td>
<td>Short SAGE (Vadu) + HDSS (Vadu)</td>
<td>Short SAGE (Vadu) + Full SAGE (Vadu) + HDSS (Vadu)</td>
<td>Short SAGE (Vadu) + Full SAGE (India) + HDSS (Vadu) + Census 2011 (India)</td>
</tr>
<tr>
<td><strong>Statistical methods</strong></td>
<td>Structural Equation Model</td>
<td>Cox Proportional Hazard Model</td>
<td>Hierarchical Ordered Probit Model</td>
<td>Multilevel Logistic Regression Model, Bayesian Logistic Regression Model</td>
</tr>
<tr>
<td><strong>Statistical software</strong></td>
<td>LISREL 8.8</td>
<td>Stata 11</td>
<td>Stata 11</td>
<td>Stata 11</td>
</tr>
</tbody>
</table>
**Structural equation modeling**

We chose the SEM approach to understand the direct and indirect effects of social and other factors on a complex latent construct such as SRH as it allowed, unlike the more traditional regression models, the use of both latent and observed variables within one framework [231-235].

![Figure 7: A hypothetical Structural Equation Model. (Source: Jöreskog et al, 1996 [236])](image)

The SEM approach is used to test a theory or hypothesis, and not as an exploratory technique. Figure 7 is a graphical representation of a hypothetical structural equation model that may be seen as a synthesis of two distinct yet interlinked processes – the measurement model (confirmatory factor analysis) relates latent variables $\xi$ and $\eta$ with their respective indicators (observed variables $X$ and $Y$) as shown by the equation,

\[
y = \tau_y + \Lambda_y \eta + \varepsilon \quad \text{(Measurement model for } y)\]

\[
x = \tau_x + \Lambda_x \xi + \delta \quad \text{(Measurement model for } x)\]
and the structural model (pathway analysis) that simultaneously regresses the endogenous latent variables (\( \eta \)) on the exogenous variables (\( \xi \)) shown by the equation,

\[
\eta = \alpha + B\eta + \Gamma\xi + \zeta \quad \text{(Structural model for latent variables)}
\]

where \( \Lambda_y \) and \( \Lambda_x \) are matrices of factor loadings that link observed variables \( y \) and \( x \) with their respective endogenous latent variables \( \eta \) and exogenous latent variable \( \xi \); \( B \) and \( \Gamma \) are matrices of regression coefficients that specify the effects between endogenous variables and between endogenous and exogenous latent variables respectively; \( \varepsilon \) and \( \delta \) are the measurement errors for observed variables \( y \) and \( x \) respectively; and \( \zeta \) is the vector of disturbance error (structural error of the endogenous latent variables \( \eta \)).

The SEM approach allows the theory formulated in the structural model to be tested with the empirics represented in the measurement model. Traditional regression assumes independent variables are measured without error; the measurement error of independent variables becomes part of the unexplained variation seen in the dependent variable. In contrast, SEM is able to explicitly account for the measurement error (\( \varepsilon \) and \( \delta \)) in the observed variables in the measurement model that otherwise would attenuate the effects in the structural model. In traditional regression, collinear variables are dropped leading to exclusion of important explanatory variables. In contrast, SEM helps reduce the impact of collinearity. Other strengths of SEM over traditional regression models are more flexible assumptions, ability to model multiple dependent variables, account for measurement error in the observed variables, and ability to handle non-normal data and incomplete data. A limitation of SEM is a lack of consensus on model fit indices. SEM is still evolving with newer and more sophisticated statistical procedures being developed especially for model fit indices [237-241].

**Cox Proportional Hazard modeling**

We chose the semi-parametric Cox Proportional Hazard model [242] to estimate the mortality hazard at time (\( t \)) for an individual with a specified vector of predictor variables (\( X \)).

\[
h(t, X) = h_0(t) * \exp \left( \sum_{i=1}^{p} \beta_i X_i \right) \quad \text{(Cox PH model)}
\]
The hazard at time \( t \) is a product of two quantities – the baseline hazard (\( h_0(t) \)) and the exponential expression of the linear sum of \( \beta_iX_i \) summed over the \( p \) predictor variables. The proportional hazard assumption is evident in the model where the baseline hazard is a function of time \( t \) but is independent of \( X \). The predictor variables \( (X_i) \) in the model are time-invariant as is evident from the exponential expression, which does not involve time \( t \). All parameters are estimated by maximum likelihood. The hazard ratio (interpreted similar to an odds ratio) is calculated as

\[
\hat{HR} = \exp \left( \sum_{i=1}^{p} \beta_i (X_i^* - X_i) \right) \quad \text{(Hazard Ratio)}
\]

Where \( X^* \) denotes the set of predictor variables for one individual and \( X \) for another individual. We tested the proportional hazard assumption (i.e. the hazard ratio was constant over time or equivalently that the hazard for one individual was proportional to the hazard for any other individual, where the proportionality constant (\( \hat{\theta} \)) was independent of time).

\[
\hat{h}(t, X^*) = \hat{\theta} \cdot \hat{h}(t, X) \quad \text{(Proportional Hazard assumption)}
\]

We chose the Cox model for analysis as even though the baseline hazard function (\( h_0(t) \)) is not specified, reasonably good estimates of regression coefficients, hazard ratios and survival curves are obtained. The Cox model is a robust model and the results closely approximate a correctly specified parametric model.

**Hierarchical Ordered Probit Modeling**

We based our vignette analysis on the statistical approach proposed by Tandon et al. and Bago D’Uva et al. [162, 170]. If we assume that the discrete response category \( (y_i=k) \) that the respondent chooses to best describe his own health is generated from an underlying continuous latent variable \( (y^*_i) \), then the probability of observing response category \( k \) conditional on covariates \( X \) is specified by a standard ordered probit model (1a, 1b) as follows,

\[
y_i^* = \beta X_i + \varepsilon_i \quad \text{(1a)}
\]

\[
y_i = k \iff \tau_i^{k-1} \leq y_i^* < \tau_i^k, \quad -\infty = \tau_i^0 < \tau_i^1 < \cdots < \tau_i^{K-1} < \tau_i^K = +\infty \quad \text{(1b)}
\]

\[
\tau_i^k = \gamma^k X_i \quad \text{(1c)}
\]
where $\tau^k = 1, \ldots, K-1$, are the thresholds the respondent use to distinguish between different categories. We further allow the thresholds to be dependent on covariates by a relationship specified by $\gamma^k$ as a natural way to model reporting heterogeneity (1c).

The standard ordered probit model is under-identified and estimation of $\beta$ separately from $\gamma^k$ is possible only when additional information on reporting heterogeneity ($\gamma^k$) is provided by anchoring vignettes as follows,

$$V_{ij} = \alpha_j + \xi_{ij} \quad (2a)$$

$$V_{ij} = k \iff v^k_i \leq V_i^* < v^{k+1}_i; \quad -\infty = v^0_i < v^1_i < \cdots < v^{K-1}_i < v^K_i = +\infty \quad (2b)$$

$$\tau^k_i = v^k_i = y^kX_i \quad (2c)$$

Similar to self-rating responses, we assume that the discrete response ($V_i$) that the individual chooses to best describe the health state depicted by the vignette is generated from an underlying continuous latent variable ($V^*_i$). The vignette response is modeled (2a) only with an intercept and error term ($\beta X$ term is omitted) as we assume that the fixed level of health state depicted by the vignette is understood in the same way by all individuals. We further forced the response category thresholds that the individual used for rating self ($\tau^k$) as well as the vignette ($\gamma^k$) to be identical (2c). The thresholds in turn are allowed to vary by covariates to model for reporting heterogeneity.

The equations (1a), (1b), (2a), (2b) and (2c) are combined as the hierarchical ordered probit (HOPIT) model to identify and adjust self-rating responses for reporting heterogeneity.

We also tested two crucial assumptions for the use of vignettes – response consistency and vignette equivalence. To recall, response consistency means that the individual uses the same thresholds to rate the vignettes as for rating self and vignette equivalence means that all individuals understand the fixed level of trait depicted by the vignette in the same way. To test the assumption of response consistency, additional information on objective measures of health was required. Such objective measures are presumed to capture all the co-variation between the latent construct of interest and the observable characteristics that may influence reporting heterogeneity. If so, then any systematic variation that is seen in self-assessment
that remains after conditioning on these objective measures can be attributed to reporting heterogeneity. We specified a variation of the HOPIT model [170] as follows,

\[ V_{ij}^* = \alpha_j + \xi_{ij} \quad (2a) \]
\[ V_{ij} = k \iff \nu_i^{k-1} \leq V_{ij}^* < \nu_i^k; \quad -\infty = \nu_i^0 < \nu_i^1 < \cdots < \nu_i^{K-1} < \nu_i^K = +\infty \quad (2b) \]
\[ y_i^* = \beta_o H_{oi} + \eta_i \quad (3a) \]
\[ \tau_i^k = \nu_i^k = \gamma^k X_i \quad (1c, 2c) \]

We combined equation (3a) that specifies the relationship between the true health state \( (y_i^*) \) and a set of objective health measures \( (H_{oi}) \), and the vignettes model (2a – 2b), and also forced the response category thresholds to be identical when rating self and all vignettes (1c, 2c). We did a Wald test for threshold parameters \( (\gamma^k) \) of all covariates to be equal to zero (global test for response consistency) and for the threshold parameter of individual covariates to be equal to zero to determine which covariates influenced response consistency. The test for response consistency is subject to the assumption of vignette equivalence.

The test for vignette equivalence assumption tests that there is no systematic variation in the perceived differences in the health states described by any two vignettes based on the observation that the perceived location (on the latent scale) of the vignettes is constant if vignette equivalence assumption holds. To test vignette equivalence, we specified a generalized ordered probit model as follows [170],

\[ V_{ij}^* = \alpha_j + \lambda_j X_i^0 + \xi_{ij}, \quad j \neq 5 \quad (2a') \]
\[ V_{ij} = k \iff \nu_i^{k-1} \leq V_{ij}^* < \nu_i^k; \quad -\infty = \nu_i^0 < \nu_i^1 < \cdots < \nu_i^{K-1} < \nu_i^K = +\infty \quad (2b) \]
\[ \nu_i^k = \gamma_i^k X_i \quad (2c) \]

The model included interactions \( (\lambda_j) \) between each covariate and all except one vignette viz. vignette severity level 5 (2a’). Including covariate interactions with all vignettes would under-identify the model. We allowed the thresholds to vary \( (\gamma_i^k) \) by covariates (2c). We did a Wald test for the parameters \( (\lambda_j) \) of all covariate-vignette interactions to be equal to zero (global test for vignette equivalence) and for individual covariate interactions to determine which
covariates influenced vignette equivalence. The test for vignette equivalence is subject to the assumption of response consistency.

**Model-based Small Area Estimation**

There is no agreement on which small area estimation method is the most optimum for a particular estimate [175]. For simplicity, we re-categorized the SRH response as a binary variable. We compared small area estimates for ‘good SRH’ prevalence derived by four different methods. The indirect synthetic method is popular for its ease of use. We grouped individuals into eight groups ($k=1, \ldots, 8$) according to sex and age. We computed the estimated district specific prevalence ($\hat{p}_j$),

$$\hat{p}_j = \sum_{k=1}^{8} \frac{n_{jk}}{n_j} \hat{p}_k$$  \hspace{1cm} (4)

where $n_{jk}$ is the census count in demographic group $k$ in district $j$, $n_j$ is the total census count in district $j$, and $\hat{p}_k$ is the estimated prevalence rate for demographic group $k$ at the state level. A 95% credible interval was estimated via Monte Carlo Markov Chain (MCMC) simulation.

Next, we developed a logistic regression model (appropriate for a binary dependent variable) with a random effect for the district level.

$$\text{logit}(p_{ij}) = X_{ij}B + u_j$$  \hspace{1cm} (5)

We used two routines (multilevel logistic regression model (MLRA) and generalized linear and latent mixed model (GLLAMM)) where $B$ is a vector of fixed effects of covariates $X$, and $u_j$ is a vector of random effects of district specific residuals. We predicted $p_{ij}$ for each individual, computed the expected prevalence estimate ($\hat{p}_{jk}$), for each demographic group in each district and then the expected district specific prevalence estimate ($\hat{p}_j$) (equation 4). We included the random effect term in the model but excluded individual values of the random effects while computing the expected prevalence estimates. None of the district level variables were statistically significant and were excluded in the final model. Both routines provided empirical best linear unbiased predictions (EBLUP) post-estimation of the
random parameters (estimates and their prediction and standard error) given the observed data.

Lastly, we developed the same model described above (equation 5) using the Bayesian approach to obtain Hierarchical Bayes (HB) estimates considered to be relatively more robust than EBLUP estimates [193]

\[ Y_{ij} \sim Bern(p_{ij}) \]

\[ \text{logit}(p_{ij}) = X_{ij}B + u_j \]

\[ u_j \sim N(0, \sigma_u^2) \]

We assumed a Bernoulli distribution with probability \( p_{ij} \) for the outcome. We defined a logistic regression model with random effect \((u_j)\) for each district to be distributed normally with mean 0 and variance \((\sigma_u^2)\). We used the likelihood function in conjunction with non-informative priors to estimate the posterior distributions for the \( \beta \) coefficients and random effect and their prediction error parameters. We used the mean of the posterior distributions of the parameters to compute the district-specific prevalence estimates in the same way as for the other approaches. We finally compared the estimates and their prediction errors derived indirectly from the national SAGE ‘large area’ survey with the estimate derived directly from the SAGE (small area) survey in Vadu.
Chapter 3: Results

The full version of the SAGE survey was administered to 321 individuals (response rate 64%) in Vadu. Twenty five percent (125 individuals) could not be reached as they had migrated or because of incorrect address. Eleven percent (54 individuals) refused or could not be administered the full questionnaire due to poor comprehension ability. The non-responders did not differ significantly from the responders in age, sex, education or other socio-demographic characteristics (results not shown). The proportion for missing information for any variable was less than 2%. Out of 6000 individuals sampled from the HDSS database for the short version of SAGE, 568 (9%) individuals could not be traced due to incorrect address or out-migration. There were no refusals and a total of 5432 individuals participated in the short SAGE survey.

Table 4: Comparative profile of salient individual and household socio-demographic characteristics of SAGE survey participants and Vadu HDSS population.

<table>
<thead>
<tr>
<th></th>
<th>Full SAGE (India)</th>
<th>HDSS (Vadu)</th>
<th>SAGE-long (Vadu)</th>
<th>SAGE-short (Vadu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of subjects 50y and above</td>
<td>7,150</td>
<td>9,801</td>
<td>321</td>
<td>5,432</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 50 – 59y</td>
<td>44%</td>
<td>45%</td>
<td>38%</td>
<td>40%</td>
</tr>
<tr>
<td>- 60 – 69y</td>
<td>40%</td>
<td>32%</td>
<td>41%</td>
<td>37%</td>
</tr>
<tr>
<td>- 70 – 79y</td>
<td>13%</td>
<td>17%</td>
<td>17%</td>
<td>18%</td>
</tr>
<tr>
<td>- 80+y</td>
<td>3%</td>
<td>6%</td>
<td>4%</td>
<td>5%</td>
</tr>
<tr>
<td>Males</td>
<td>51%</td>
<td>52%</td>
<td>51%</td>
<td>52%</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- no formal education</td>
<td>51%</td>
<td>63%</td>
<td>60%</td>
<td>55%</td>
</tr>
<tr>
<td>- primary or less</td>
<td>25%</td>
<td>14%</td>
<td>20%</td>
<td>35%</td>
</tr>
<tr>
<td>- secondary and above</td>
<td>24%</td>
<td>23%</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>No spousal support</td>
<td>26%</td>
<td>23%</td>
<td>24%</td>
<td>22%</td>
</tr>
<tr>
<td>Household socioeconomic status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- no toilet facility</td>
<td>52%</td>
<td>64%</td>
<td>64%</td>
<td>63%</td>
</tr>
<tr>
<td>- electricity at home</td>
<td>68%</td>
<td>88%</td>
<td>88%</td>
<td>90%</td>
</tr>
<tr>
<td>- private drinking water supply</td>
<td>26%</td>
<td>43%</td>
<td>50%</td>
<td>48%</td>
</tr>
</tbody>
</table>
The socio-demographic characteristics of the individuals included in both the short and full version of the SAGE survey were similar to the Vadu HDSS population from which they were sampled. However, the Vadu SAGE participants were significantly older (21% and 23% above 70 years age) compared to the national SAGE survey participants (16% above 70 years age).

There was no significant difference in the sex distribution (males 51 to 52%) between the Vadu and national SAGE participants (Table 4). A significantly higher proportion (55% and 60%) of SAGE participants from Vadu had no formal education compared to the national SAGE participants (51%). The absence of spousal support was similar (22% to 26%) in all the SAGE surveys. A significantly higher proportion of the Vadu SAGE participants had access to their own private drinking water supply (48% and 50%) compared to participants from the national SAGE survey (26%). In contrast, a significantly lower proportion (36% and 37%) of Vadu SAGE participants had access to toilet facilities compared to the national SAGE survey participants (48%).

**Self-rated health – understanding pathways**

We considered a simple theory (Figure 8) where individual socio-demographic characteristics such as age, sex, education, and socioeconomic status directly and/or indirectly influenced quality of life and SRH through intermediate mediators such as functional ability and social networking. We hypothesized that age had an indirect effect on SRH mediated through ability to function in various health domains while sex had a direct effect on quality of life, which in turn influenced SRH. We also hypothesized that socioeconomic status had direct and indirect effects on SRH mediated through the individual’s social networking and social cohesion. Risk behaviour was hypothesized to influence SRH and quality of life mediated through chronic illness. Finally we hypothesized that quality of life had a direct effect on SRH but not vice versa.
Figure 8: Structural equation model for SRH. Standardized coefficients (effects) are shown in parenthesis. Latent variables are depicted as ovals and observed variables as rectangles. Final model $\chi^2 = 409.87$, $df = 271$; RMSEA = 0.041 (Source: Hirve et al, 2013 [228])

All observed indicators retained in the measurement model had significant loadings and the results (not shown) indicated that the latent constructs were well represented by their observed indicators. The final model had a $\chi^2/df$ ratio of less than 2 and together with a RMSEA of less than 0.05 suggested an acceptable fit of the model to the data. Older individuals reported poorer SRH and quality of life compared to those younger. The effect of age on SRH was mediated through functional ability – increased limitation of ability to function in any of the health domains was associated with higher reporting of poor SRH (standardized $\beta=0.90$). The magnitude of the standardized coefficient suggested that age and functional ability had large effects on SRH. Higher socioeconomic status and higher quality of life was in turn associated with better SRH but this relationship lacked statistical significance. Women rated their quality of life and SRH poorer than men. A higher level of social networking was seen amongst those better educated and with a regular income, which in turn was
associated with a higher quality of life. Smoking or consumption of tobacco was associated with at least one chronic illness, which in turn was associated with poor SRH and quality of life. However the association between chronic illness and SRH and quality of life was not statistically significant.

**Self-rated health – predicting mortality**

Out of 5432 individuals included in the short SAGE survey in Vadu in 2007, we were able to link records of 5087 (94%) participants with the information from HDSS rounds till June 2011 (four years follow up since SAGE interview). The age and sex profile of those individuals on whom follow up information on mortality was not available (mean age – 64.2 years, SD – 8.8 years; males – 52%) was similar to those who were followed up in subsequent HDSS rounds (mean age – 63.1 years, SD – 8.9 years; males – 52%).

![Smoothed estimates of hazard function for mortality stratified by socio-demographic characteristics](image-url)

Figure 9: Smoothed estimates of hazard function for mortality stratified by socio-demographic characteristics
The increase in mortality hazard function over time was greater for older individuals and those who were poor compared to those who were younger and richer (Figure 9). It was also higher for men compared to women. The absence of spousal support increased the mortality hazard, being highest for men without spousal support.

Figure 10 shows the adjusted hazard ratio with 95% confidence intervals for mortality derived separately for men and women from the Cox proportional hazard model.

Figure 10: Hazard ratio for mortality. Reference categories are ‘good/very good SRH’, ‘50-59 years age’, ‘spousal support’, ‘primary or less education’, and ‘poorest socioeconomic quintile’.
Mortality hazard was significantly higher in individuals who reported ‘bad / very bad’ SRH (HR = 3.06; 95% CI: 1.93 – 4.87) compared to those who reported ‘good / very good’ SRH in men. A similar trend was seen in women (HR = 1.64; 95% CI: 0.94 – 2.86) but was not statistically significant after adjusting for disability. The hazard for mortality was significantly higher amongst older individuals aged 80 years and above both amongst men (HR = 5.43; 95% CI: 3.30 – 8.85) and women (HR = 7.29; 95% CI: 4.31 – 12.32) compared to those aged 50 to less than 60 years. Absence of spousal support increased the hazard for mortality by about 67% (95% CI: 1.23 – 2.26) in men and 71% (95% CI: 1.21 – 2.41) in women. Mortality hazard was not significantly influenced by education and socioeconomic status. However there was a significant increase in the hazard for mortality (23% in men and 16% in women) for every unit increment in the standardized disability WHODAS score after adjustment for SRH, age, sex, socioeconomic status and education (Figure 10).

There was no significant interaction between the socio-demographic covariates (spousal support, education, socioeconomic status) or disability and SRH in predicting mortality either in men or women (results not shown).

**Self-rated health – interpersonal comparability**

Of the 5432 individuals included in the SAGE survey in Vadu, 5086 (94%) individuals were administered vignettes (345 individuals had to be excluded as their identity information could not be linked with the HDSS dataset and one individual was not administered vignettes). Of the 5086 individuals, 1307 were administered mobility/affect vignettes, 1251 self-care/cognition, 1287 pain/relationships and 1241 were administered sleep/vision vignettes. We restricted our vignettes analysis to the mobility and cognition as objective measures to assess response consistency were available only for these two domains.

Overall about 39% of individuals reported no difficulty and a similar proportion reported mild difficulty in ability to function in any of the health domains (Figure 11). The least functional disability was reported in self-care (no difficulty in bathing – 56%; no difficulty in maintaining appearance – 51%). Overall, about one in five individuals reported moderate or greater difficulty in functional ability across all domains. The highest functional disability was reported for performing vigorous activity (41%), pain (30%) and vision (26%).
Figure 11: Reported difficulty in functional ability in eight health domains.

Figure 12 illustrates the problem of reporting heterogeneity. It uses information from five vignette ratings to identify reporting heterogeneity in the self-ratings for men and women for mobility. The survey question asked was “Overall in the last 30 days, how much difficulty did you / [vignette character name] have in moving around?” Vignettes are placed from left to right in order of increasing severity of the health state they describe.
In this example, men gave more favourable ratings (higher proportion reported no difficulty) than women for any given vignette conditional on the fixed level of mobility described by the vignette. In other words, men probably used different thresholds to rate the same vignettes describing fixed levels of mobility compared to women. By the same logic, the thresholds used by men would be different from that used by women when they responded to the self-assessment question.

The problem of reporting heterogeneity is further illustrated by Figures 13 and 14. The proportion of individuals that reported no difficulty or moderate difficulty for the same vignette that described a fixed level of mobility, varied with age of the individual (Figure 13). Similarly, the proportion of men that reported mild or moderate or severe difficulty for the same vignette that described a fixed level of cognition was different from that of women (Figure 14).

**Figure 13:** Variation in vignette rating across age groups. Responses are for the mobility vignette “[xxx] does not exercise. S/he cannot climb stairs nor do other physical activities because s/he is obese. S/he is able to carry the groceries and do some light housework. Overall in the last 30 days, how much of a problem did [xxx] have in vigorous activity?”
The assumption of vignette equivalence was upheld in all domains except in the learning sub-domain of cognition and washing sub-domain of self-care (results not shown). The assumption of response consistency was tested only for mobility and cognition vignettes, as additional information on objective measures was available only for these domains. The global tests showed that the assumption of response consistency was not met for both mobility and cognition vignettes (refer to Table 4 in paper # 3) largely driven by age, sex, SES and education. A visual comparison showed the predicted thresholds from the cognition vignettes model to be slightly different from that of the objective measures model (refer to Figure 2 in paper # 3). The two sets of thresholds predicted from entirely different set of variables (cognition vignettes and cognition test scores) seemed to be concordant. Thresholds were also similar for the ‘vigorous activity’ subdomain. However the thresholds predicted from the vignette and objective measures models were less similar for the ‘moving around’ subdomain of mobility.

Our results showed that there was strong evidence of systematic variation in reporting behavior when individuals were asked to self-rate their functional ability. Individuals with higher socioeconomic status and higher education significantly lowered the ‘none-mild' response category threshold for cognition ratings i.e. they were more

Figure 14: Variation in vignette rating across sex. Responses are for the cognition vignette “[xxx] can concentrate while watching television, reading a magazine or playing a game of cards or chess. S/he can learn new variations in these games with small effort. Once a week s/he forgets where the keys or glasses are, but finds them within five minutes. Overall in the last 30 days, how much of a problem did [xxx] have in learning a new task (for example, learning how to get to a new place, learning a new game, learning a new recipe)?”
likely to be ‘demanding’ in self-rating their cognitive ability compared to lower socioeconomic status and less educated respondents. After correction for reporting heterogeneity, women, older individuals and those from lower socioeconomic background, were significantly more likely to report greater difficulty in mobility. A similar pattern was seen for cognition self-rating but was not significant.

Self-rated health – small area large area comparisons

We used four different sources of data for this analysis – (1) the national SAGE survey dataset for India was used to indirectly derive district level estimates using auxiliary information from (2) the Census of India 2011 and also to indirectly derive an estimate for Vadu using auxiliary information from (3) the Vadu HDSS dataset. This indirectly derived Vadu estimate was then compared with the estimate directly derived from the (4) the short version of the SAGE survey dataset for Vadu. From the national SAGE survey for India, we included only those 630 individuals from the rural strata of Maharashtra state so as to make them comparable to the Vadu rural population. The age (mean 62 years) and sex (men 51%) composition of individuals from the Maharashtra SAGE survey and Vadu survey was similar. Individuals from the Vadu survey were significantly better-educated and reported lower disability levels (WHODAS score 20.8) and better quality of life (WHOQOL score 72.2) as compared to those from Maharashtra (WHODAS score 28.4 and WHOQOL score 57.0). Only three of the 21 districts sampled in the Maharashtra SAGE survey had more than fifty individuals, generally considered as a minimum sample required estimating prevalence. The median sample size was 30 individuals per district (range: 14 to 81 individuals).

Figure 15 shows the HB estimate and GLLAMM estimate for good SRH prevalence plotted against the direct survey estimate for each district. For most districts, the HB estimates show closer approximation to the direct survey estimates than the GLLAMM estimates.
The correlation between the model-based estimates (MLRA, GLLAMM and HB) was high (greater than 0.95). The correlation between the model-based estimates and the direct survey estimate was around 0.75 (results not shown).

The direct survey prevalence estimate of ‘good’ SRH at the state level was 23.3% (95% credible intervals 20.0%-26.7%). At the district level, the estimate varied from 4.8% to 47.1% with very wide 95% credible intervals that reflected the small sample size for each district. The prevalence estimate of ‘good’ SRH in Vadu was 50.1% as estimated directly from the Vadu SAGE survey (Table 5).
Table 5: Comparison of prevalence estimates for Vadu (small area) derived indirectly from the national SAGE (large area) survey in India using different small area estimation methods with direct survey estimates from the Vadu SAGE survey (n=319). (Source: Hirve et al., 2013 [230])

<table>
<thead>
<tr>
<th>Method</th>
<th>Good SRH prevalence estimate</th>
<th>95% confidence / credible interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct survey weighted</td>
<td>50.1%</td>
<td>44.5% - 55.6%</td>
</tr>
<tr>
<td>Indirect synthetic</td>
<td>24.2%</td>
<td>19.7% - 29.2%</td>
</tr>
<tr>
<td>MLRA</td>
<td>45.6%</td>
<td>42.8% - 48.3%</td>
</tr>
<tr>
<td>GLLAMM</td>
<td>45.7%</td>
<td>43.0% - 48.4%</td>
</tr>
<tr>
<td>Hierarchical Bayesian</td>
<td>45.2%</td>
<td>42.5% - 48.0%</td>
</tr>
</tbody>
</table>

The model-based estimates (MLRA-45.6%, GLLAMM-45.7%, HB-45.2%) for Vadu were similar with tighter 95% credible intervals and not substantially different from the direct survey estimate. The indirect synthetic estimate for Vadu (23.2%) was a poor approximation to the direct survey or model-based estimate.
Chapter 4: Discussion

The niche

Despite its widespread use and utility as a predictor of health outcomes, SRH is a complex latent construct as yet poorly understood. Though much is known globally about the psychosocial determinants of SRH, the pathways through which they and other determinants influence SRH are unclear. Moreover, the evidence base is largely from populations in high-income countries due to lack of research priority and adequate scientific infrastructure in low- and middle-income countries. The potential of SRH as a measure of health and a predictor of health outcomes in the context of an aging population in low- and middle-income countries is yet not fully explored. Aging is a multidimensional multifaceted process encompassing a broad range of biological and social issues in key life domains like health, disability, cognition, activities of daily living, work, family, security, caring and well-being. Historically aging research has revolved around specific disease and life stages and been confined to the neurosciences, geriatrics, psychology, and demography amongst others. Till recently there was no common scientific platform that covered all the key life domains and could address the needs of an interdisciplinary approach to aging research. The rapid demographic transition witnessed globally has provided the impetus to establish HRS-type longitudinal studies throughout Europe and Asia. The SAGE is one such data initiative that aims to establish a credible scientific harmonized data infrastructure in low- and middle-income countries. The first wave of the SAGE survey provides an opportunity to explore the complex construct of SRH in low- and middle-income settings within the context of a rapidly aging population.

The unique selling point

Our research addresses specific knowledge gaps and builds on the existing knowledge about SRH. It provides an early evidence base, so far lacking in low- and middle-income countries. It used recent advances in statistical methodologies to better understand the complex construct of SRH from four different perspectives – understanding pathways, role as a predictor of mortality, issues of reporting heterogeneity in SRH, and the validity of SRH estimates derived indirectly from large national surveys using small area
estimation techniques. It created value addition by linking cross-sectional SAGE survey data with longitudinal HDSS data. Such data linkages allowed us to address research questions that were beyond the scope of the original SAGE survey research.

**The value addition**

Our research provides new understanding of the complex pathways through which social environment, functional limitation in performing activities of daily life, chronic disease experience and other factors influence SRH. It furthers our understanding of the indirect effect of age on SRH mediated through functional ability and the indirect effect of socioeconomic status and education on quality of life mediated through social networking seen in other studies [115-118]. The effect of low education and material deprivation has been seen in both Western and post-Communist populations partly mediated by perceived lack of control [109]. The lack of a significant direct effect of socioeconomic status on SRH could be explained by a stronger but indirect effect mediated through social networking. It was also possible that older adults perceive their social trust and capital to be as important if not more, than their economic status for rating good health and well-being. The role of contextual factors in determining perceived health has been seen [113]. Higher level of community level social trust is associated with better-reported health. However this effect becomes statistically insignificant after controlling for individual trust perception. The hypothesis that socially disadvantaged individuals may not perceive or report illness because their assessment of their own health is contingent on their social experience [90] may possibly explain the lack of a statistically significant association between disease experience and SRH seen in our research. Our finding that the presence of a living spouse as an indicator for functional ability that in turn influenced SRH is consistent with a study amongst elderly in south India [105] and highlights the importance of emotional and physical support by the spouse of family beyond just economic security. We note here some limitations of our approach – the structural equation modelling approach that we used is never able to prove causality. However it can test causal pathways with cross-sectional data though less convincingly than with longitudinal data. Finally our findings were limited by the conceptual theory that we tested and the constraints on relationships that we imposed on our theory.
The ‘timeless’ debate

Linking the cross-sectional SAGE survey with the HDSS database provided a longitudinal dimension to our research. It allowed us to confirm the predictive role of SRH for mortality seen in many other studies, particularly those from developed countries [140]. However, the scope of our dataset forced us to treat SRH as a time-invariant variable and hence its utility and validity can be questioned especially if it had been reported far earlier to the death event. This brings up the larger debate about what exactly is being measured in a SRH response. The exact wordings and response options of the SRH question has varied with different surveys. Others have argued that though the level and distribution are not directly comparable between differently worded SRH questions, they represent the same phenomenon and show concordant answers [81]. By asking as in our study, ‘in general, how would you rate your health today?’ short-term fluctuations in health are captured such as mild illness or even some normal cyclical variation in well-being. This can add noise to attempts to establish better predictive power of SRH for long-term health outcomes such as mortality. Researchers have tried to address this concern by specifying different time anchors for the global SRH question while yet others have tried to specify different terminologies – ‘health’ to mean more general health and ‘health status’ to mean current health – to describe such time span differences. A stable alternative may be to ask the global question with a broader time frame, maybe a week or month. Others have argued the need for a time reference for the SRH question to be able to distinguish between ‘perceived current health’ that predicts health service utilization and medication use from ‘perceived general health’ which is more global in its perspective and predicts health outcomes such as mortality [243]. This distinction between ‘perceived general health’ and ‘perceived current health’ is not merely academic but crucial to the understanding of SRH. It was beyond the scope of our study to make a distinction between these concepts.

We also note here that our study was limited to some extent by survivor bias as the study by design, excluded individuals who died before attaining 50 years age. It is likely that the mortality hazard for poor SRH is likely to be underestimated in the survivor group (those who survived beyond 50 years age). However, this underestimation is likely to be small, as the mortality hazard is known to be lower for younger adults.
The basic problem

Discourse in social science measurement has largely been dominated by data collection, measurement error and ordinal variables. Social scientists agree to improve methods of data collection through improved tools, and reduce measurement error by embracing methods such as Linear Structural Relations. The ‘ordinal – interval’ debate revolves around whether the latent variable which underlies the manifest ordinal variable, is discrete or interval. However, the lack of interpersonal comparability in ordinal responses may pose a more serious challenge than either errors in measurement or the debate on the most appropriate statistical way to handle ordinal data [244]. Researchers have tried to address the problem of interpersonal and cross-cultural incomparability by attempts to improve the wording of the survey question, cognitive debriefing and other techniques. Only recently have newer techniques like anchoring vignettes [149] been proposed to address this problem. Given the complexity of overall general health, opinion is divided whether anchoring vignettes can be used for such a complex construct though one study tested anchoring vignettes specifically designed to calibrate the SRH question [151]. Our use of anchoring vignettes was limited to the self-assessment questions in the eight health domains for which anchoring vignettes were administered as part of the SAGE survey. Our research found strong evidence of reporting heterogeneity when individuals were asked to self-rate their mobility and cognitive ability largely driven by education and socioeconomic status.

Our research also demonstrates the importance to test for vignette equivalence and response consistency as pre-requisite conditions to be met prior to the use of anchoring vignettes for adjusting self-rating responses for reporting heterogeneity. These assumptions are themselves a function of the anchoring vignettes as well as the self-rating questions – how they are worded, how they are understood by different cultures and individuals, and how individuals respond to them on an ordinal scale – and a failure to meet these assumptions does not necessarily discredit the individual’s self-rating or vignette rating response. Instead, one may attempt alternate approaches – collapsing response categories, testing assumptions with a smaller set of vignettes after excluding the less informative vignettes etc. However, it is important to stress the need to test for assumptions that may potentially preclude the use of anchoring vignettes to identify and adjust self-rating responses for reporting heterogeneity. We also highlight that though the technique of anchoring vignettes
allowed us to identify and adjust self-rating responses for reporting heterogeneity, it did not help explain the reasons for the differences in reporting behaviors. Finally, as a note of caution, anchoring vignettes may be used to correct differential reporting behavior only, not for all forms of differential item functioning [245]. If respondents understand and interpret the rating question in fundamentally different ways, then anchoring vignettes may only partly fix the inferential problems. The question still remains on how to address these other aspects of interpersonal incomparability aside from reporting heterogeneity.

**A unique opportunity**

HDSS are effective platforms that capture health dynamics and social transitions in society. They can support observation and intervention studies that can provide the evidence base for policy formulation. Their potential contribution to local and national health policy remains untapped [246]. Linking the national SAGE survey with the Census data and the Vadu HDSS data allowed us a unique opportunity to compare estimates of ‘good’ SRH for Vadu (small area) derived indirectly from the national (large area) SAGE survey with estimates derived directly from the Vadu SAGE survey using different design- and model-based small area estimation methods. Small area estimation techniques are increasingly used for disease mapping and to analyse area-level disease burden. However, there is no consensus on which small area estimation method makes the most accurate estimates with the smallest prediction error. The two main challenges of small area estimation are calculating the estimate with any level of precision given the small sample size at the small area level and estimating its standard or prediction error. Our research confirmed that model-based methods that derive empirical Bayes and hierarchical Bayes estimates have a distinct edge over the more traditional indirect synthetic methods in estimating more precise estimates [175]. The indirect synthetic method was obviously biased as it incorrectly assumed that the difference in SRH estimates was solely due to the age and sex compositional differences between areas [247]. On the other hand, the multilevel regression model used the best linear unbiased prediction to estimate the random effects and allowed for the influence of contextual factors to provide unbiased estimates of their standard errors [248]. However these variances tend to be overly optimistic. The hierarchical Bayes estimate, in turn, accounted for this uncertainty in the prediction error. These estimates are relatively robust to variations in sample size of each small area
However, the precision of these and any model-based estimates is limited by the availability of covariates common to both the survey and the auxiliary (census) data. More generally, these methods can be applied for other health outcome measures such as prevalence of chronic conditions, disability etc. that will help improve planning and evaluating intervention strategies for healthy aging by local health agencies with limited resources.
What next? – Conclusions and Implications

Our research is timed to raise awareness and stimulate the scientific community and policy makers to prioritize and mainstream healthy aging into the national research and development agenda for countries such as India that are witnessing a rapidly aging population.

Our study establishes the value and utility of SRH as a measure of health and predictor of health outcomes in the context of aging in India. Such a simple measure can be used in surveys to assess health in an elderly population, to identify vulnerable communities for targeted interventions, to plan and prioritize resources and to evaluate health interventions in resource scarce communities.

Our study provides an understanding of the mediating influence of the social and physical environment and ability to function in key domains of life on health and well-being. It provides evidence to promote social policy and program interventions aimed to increase social networking and social participation amongst older adults especially those who are socially disadvantaged, those who lack spousal support, to improve their overall perception of health and well-being. It provides evidence to promote interventions that enable ability to function or reduce the effect of disability amongst older adults to perform in key life domains and activities of daily living.

Our study highlights the significant role of SRH and functional disability in predicting mortality independent of the individual’s age, sex and socioeconomic characteristics. It serves to identify individuals and groups of individuals at risk for adverse health outcomes for possible social and health interventions.

Our study highlights the methodological concern of interpersonal incomparability of responses to self-assessment questions prior to making comparisons across individuals or groups of individuals. It validates the use of ‘anchoring vignettes’ method to identify reporting heterogeneity. Our study underlines the importance of adjusting self-assessments of health for reporting heterogeneity that is largely influenced by age, sex, education and socioeconomic status, when making cross-cultural comparisons across communities.
Our study estimates the prevalence of ‘good / very good’ SRH in our population aged 50 years and above to be 50%. This direct survey estimate compared well with the prevalence estimate of about 45% derived indirectly from model-based small area estimation methods with smaller prediction error. Our study highlights the potential of using information from large national surveys by district level managers for planning and evaluation of policies and programs at the district or sub-district level.

Questions unanswered

Our research raises many interesting questions central to SRH or to the methodological approaches that are used, which are left unanswered.

A SRH response is an outcome of both an individual’s health experience and expectation. It was beyond the scope of this research to study if and how expectations modulate the pathway between experience and SRH, to understand the interplay between these two dimensions of health in generating the ‘considered’ SRH response.

A global health measure like SRH by implication needs to be insensitive to short-term changes, of what is essentially a measure of trend in the individual’s health. What does a change in global health measure signify? If health deteriorates gradually over a long period, is the ‘perceived general health’ response reset to the time when the SRH question was asked or is it set to some previous level? Does the level of ‘perceived general health’ change at all? If so, how quickly or slowly does it change? How much do any of the factors influencing SRH need to cumulate to produce a change in response? Is there a dose – response relationship? Do they change more or less amongst certain groups? What determines or triggers this change? We know that health ratings decline with age consequent to changing expectations of health with increasing age. But to what extent and why is unclear. These questions are crucial in understanding SRH but have seldom been answered. The second wave of SAGE when implemented in the same participants in 2014 may be adapted to answer some of these questions, as also explore causality.

In this research work, we explored the problem of reporting heterogeneity between individuals and groups of individuals within the Indian context. In a separate paper (not included in this thesis), we explore the problem of cross-cultural incomparability of self-
rating response across low- and middle-income countries in Asia and Africa that participated in the WHO – INDEPTH SAGE collaboration [249]. Such research would help understand the factors that may drive the geographical and cultural disparities in how populations perceive and rate their own health state.

It was beyond the scope of this research to assess some of the methodological considerations of the anchoring vignettes technique – whether administering the vignettes before or after the self-assessment question influences response consistency, or whether matching or contrasting the age and sex of the individual and the vignette character influences reporting behavior [250], or whether improving the wording of the cognition vignettes would enable individuals to better distinguish ‘memory’, a lower cognitive function based on short-term memory from ‘learning’ a higher cognitive function based on both prospective memory and executive function. Studies have shown that switching the question order (vignettes followed by the self-assessment) serves to communicate the question better and primes respondents to define the response scale in a common way [166]. It has also been seen that the vignette character’s sex may be relevant for some but not all vignettes e.g. a vignette describing a man with a headache may be rated as having worse health than a woman with a similar ailment [251, 252].

Finally, our research provides the basis and impetus to establish similar adult health and aging research platforms in different regions of India and elsewhere that are harmonized with other aging research platforms across the Americas, Europe, Asia and Africa. An aging research platform within a HDSS context would serve to institutionalize the global SRH question and a select set of health and disability questions within routine surveillance systems. Such an aging module integrated into routine HDSS would serve to monitor health trends, and evaluate public health interventions and policies. Such an integrated longitudinal platform would serve to address some of the unanswered research questions.
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