The Agincourt health and socio-demographic surveillance system (HDSS), located in rural northeast South Africa close to the Mozambique border, was established in 1992 to support district health systems development led by the post-apartheid ministry of health. The HDSS (90,000 people), based on an annual update of resident status and vital events, now supports multiple investigations into the causes and consequences of complex health, population and social transitions. Observational work includes cohorts focusing on different stages along the life course, evaluation of national policy at population, household and individual levels and examination of household responses to shocks and stresses and the resulting pathways influencing health and well-being. Trials target children and adolescents, including promoting psycho-social well-being, preventing HIV transmission and reducing metabolic disease risk. Efforts to enhance the research platform include using automated measurement techniques to estimate cause of death by verbal autopsy, full ‘reconciliation’ of in- and out-migrations, follow-up of migrants departing the study area, recording of extra-household social connections and linkage of individual HDSS records with those from sub-district clinics. Fostering effective collaborations (including INDEPTH multi-centre work in adult health and ageing and migration and urbanization), ensuring cross-site compatibility of common variables and optimizing public access to HDSS data are priorities.

Keywords
Sub-Saharan Africa, population pyramids, health transition, mortality, morbidity, cause of death, fertility, migration, census, HIV, tuberculosis, non-communicable diseases, households
Why was the Agincourt Health and Socio-Demographic Surveillance System set up?

The Agincourt Health and Socio-Demographic Surveillance System (HDSS), located in rural northeast South Africa close to the Mozambique border, provides the foundation for the Rural Public Health and Health Transitions Research Unit of the Medical Research Council (MRC) and University of the Witwatersrand, South Africa (the MRC/Wits-Agincourt Unit). Its origins lie in the university's 'Health Systems Development Unit' that in the early 1990s focused on district health systems development, sub-district health centre networks and referral systems and training of clinically oriented primary health care nurses. This was done to guide critical re-organization of the country's health system alongside democratic political change and the dismantling of South Africa's ubiquitous 'Bantustan' system, which had spawned duplicate and inefficient health departments concurrently with systematically marginalizing the rural poor. However, efforts were seriously hampered by the lack of reliable population-based information for programme planning and resource allocation.

Influenced by Sidney and Emily Kark's vision of 'community-oriented primary care', as well as visits to health and demographic surveillance sites in Bangladesh (Matlab) and Senegal (Niakhar), we established the Agincourt HDSS to address this information gap. In 1992, a baseline census was conducted in 20 contiguous villages chosen for their rural living conditions, limited access to public sector services, underperforming primary care clinics and communities of Mozambican refugees displaced by the civil war. Three phases followed the baseline census: (i) decentralized health systems development that provided a prototype for national policy in response to limited experience in delivering rural services (1993–97), (ii) reorientation to an interdisciplinary health and population research initiative to better understand the dynamics of health, population and social transitions and address serious weaknesses in the rural evidence base (1998–2002) and (iii) an established university and MRC-linked field research and training programme supporting multiple investigations into the causes and consequences of critical findings from the HDSS (2004 onwards) (www.wits.ac.za/academic/health/publichealth/agn-acourt/).

The Agincourt HDSS was a founding member of the International Network for the Demographic Evaluation of Populations and Their Health (INDEPTH) (www.indepth-network.org) and provides leadership to INDEPTH multi-centre initiatives in adult health and ageing and migration and health.

What does it cover now?

The Agincourt HDSS constitutes a platform for research programmes that elucidate causal pathways and test interventions across the life course. Figure 1 outlines the organizational framework, indicating major research themes and links between them. Critical questions relate to (i) the dynamics of rapidly evolving health, population and social transitions—including inequalities between individuals and communities and social and biological explanations, (ii) determinants of vulnerability and resilience along the life course and (iii) implications for policy, programmes and services.

Efforts have been made to deepen observational work, extend a portfolio of intervention research and enhance capacity of the platform to support research training with PhD, post-doctoral and selected masters projects nested within established research areas.

Figure 1 Research themes supported by the Agincourt HDSS, South Africa
Deepening observational work
Several cohorts are nested within the population under surveillance and generally focus on subgroups at different stages along the life course (Table 1).

The HDSS contributes to evaluation of national policy at population, household and individual levels. Examples include the following: introduction of the Rotarix® and pneumococcal conjugate vaccines into the Expanded Programme on Immunization, impact of social support grants (old age pension and child support grant) on the health and well-being of grant recipients and other household members, and the population impact of decentralized delivery of highly active anti-retroviral therapy (HAART) through public and private health systems.

In addition, a portfolio of work examines household responses to shocks and stress and the resulting pathways influencing child and adult health and well-being. This includes the care and support roles of older women, intra- and inter-household social connections, use of natural resources and diverse migration and livelihood strategies.

Extending a portfolio of intervention research
Ongoing trials target critical problems affecting the health and well-being of children and adolescents. The Kulani (‘strength’) cluster randomized trial evaluated a primary school-based intervention, developed by a non-governmental organization and conducted by the Provincial Department of Education, to improve psychological and educational outcomes of children aged 10–12 years (in partnership with the University of Oxford, UK, and Soul City Institute for Health and Development Communication, South Africa). The Swa Koteka (‘we can’) multi-level HIV prevention trial aims to reduce HIV transmission in adolescent girls by encouraging girls to remain in high school through a conditional cash transfer (individual randomization) and by influencing gender norms through community mobilization focused on men (village cluster randomization) (with the Universities of North Carolina and San Francisco, USA, and the Wits Reproductive Health and HIV Institute and Sonke Gender Justice, South Africa). The forthcoming Ntshembo trial (‘hope’) aims to reduce the intergenerational transfer of metabolic disease risk through community health worker-delivered interventions to pre-pregnant adolescent girls, which are reinforced during pregnancy and infancy. Formative studies to-date address growth and nutrition, physical activity, body image preferences, beliefs and practices regarding pregnancy, delivery and infant feeding, community food vendors and adolescent health services (with the MRC/Wits Developmental Pathways for Health Research Unit, South Africa and the Universities of Cambridge and Oxford, UK, Umeå, Sweden, and North Carolina, USA).

Enhancing capacity of the Agincourt research platform
Efforts to ensure rigour and extend analytic possibilities include application of automated measurement techniques to cause-of-death estimation by verbal autopsy, full ‘reconciliation’ of in- and out-migrations, follow-up of migrants who depart the study area and recording of extra-household social connections. Linkage of individual records in the HDSS with those from sub-district clinics is based on conventional identifiers (name, date of birth, village, ID, cell number and other household members); fingerprint matching was used to validate these variables in correctly matching clinic patients with their HDSS records.

Where is the HDSS area?
Maps in Figure 2 indicate the location of the Agincourt HDSS in northeast South Africa close to the border with Mozambique (Figure 2a), the boundary of the study site abutting on the Kruger National Park conservation area (Figure 2b) and the villages and health and education facilities within the site (Figure 2c).

The Agincourt HDSS covers an area of 420 km² comprising a sub-district of 27 villages with traditional and elected leadership. Since the democratic transition in 1994, infrastructure development has proceeded but at a rate below expectations: electricity is available in all villages, but the cost is too high for many households; few gravel roads have been tarred within the sub-district; a dam was constructed nearby, but to-date, there is no piped water to dwellings, and sanitation is rudimentary. Every village has a primary school and most a high school; however, the quality of education remains poor. Although almost all children enrol, educational progress is often delayed with few post-secondary opportunities.

The area is dry in winter (from May to October), with soil more suited to game farming than agriculture. Households generally purchase maize and other foods, supplementing this with home-grown crops and collection of wild foods. South Africa’s non-contributory social grant system is a vital source of household income, notably the old age pension and child support grant. There are two health centres and six clinics within the sub-district, with three district hospitals 25–60 km away.

Who is covered by the HDSS, and how often have they been followed up?
At baseline in 1992, 57,600 people were recorded in 8,900 households in 20 villages; by 2006, the
| Cohort name | Aim | Sample |
|-------------|-----|--------|
| **OBSERVATIONAL COHORTS** | | |
| *Ntshembo* ('Hope') | To measure metabolic disease risk in adolescent girls | 600 | Closed | Cohort recruited in 2007 | Boys and girls aged 7/8, 11/12 and 14/15 years |
| *Ha Nakekela* ('We care') | To measure HIV and non-communicable disease prevalence and their risk factors | 7428 | Closed | Baseline in 2010/2011 | Men and women 15 years and older |
| **INDEPTH-SAGE** (Survey on global AGEing and adult health) | To assess health status, well-being and health seeking behaviour of older persons | 4509 | Open | Baseline in 2006 | Population 50 years and older |
| *SEEDS* (Study of the Epidemiology of Epilepsy) | To understand the burden of epilepsy, pattern of seizures, and excess mortality in persons with epilepsy | 310 | Closed | Nine rounds completed Follow-up every 3 months | All ages diagnosed with epilepsy following screening in 2008 |
| *SUCSES* (Sustainability in Communal Socio-Ecological Systems) | To examine (i) household income, resource use, response to shocks on household livelihoods, (ii) how livelihood capital migration and use of natural resources shape household resilience and (iii) how poverty influences child nutrition | 590 individuals and their households | Closed | Round 1—2010 Round 2—2011 Round 3—2012 | Sample stratified by gender and age Four individuals selected per age/gender group in nine villages |
| **INTERVENTION COHORTS** | | |
| *Kulani* ('Grow strong') | Cluster randomized trial to test school-based interventions to promote social and emotional wellbeing of children 10–12 years | 988 individuals in 10 schools | Closed | Cohort recruited in 2009 Post-intervention follow-up end-2010 Next follow-up in 2013 | Boys and girls in grades 5 and 6 Schools |
| *Swa Koteka* ('We can') | Randomized trial to determine whether young women who receive cash transfers conditional on school attendance have a lower incidence of HIV and HSV2 infection over time | 2900 | Closed | Cohort recruited in 2011/2012 Annual follow-up for 3 years | Young women aged 13–20 years, in school grades 8–11, one girl per household Individual |
population had increased to ~70,000 people in 11,700 households. This increase is partly due to Mozambican in-migrants overlooked in the baseline survey and to a new settlement established as part of the post-apartheid government’s Reconstruction and Development Programme. In 2007, the study area was extended to include the catchment area of a new privately supported community health centre established to provide HIV treatment before public sector roll-out of HAART. By mid-2011, the population under surveillance comprised 90,000 people residing in 16,000 households in 27 villages (Table 2). Households are self-defined as ‘people who eat from the same pot of food’. Given sustained high levels of temporary labour migration in southern Africa, we included temporary migrants residing for <6 months per year who retain close ties with their rural homes in the HDSS. There have been 17 census and vital event update rounds conducted strictly annually since 2000. Participation is virtually complete, with only two households refusing to participate in 2011.

The LINC (Learning, Information dissemination and Networking with Community) office, responsible for community liaison, has built a 20-year relationship with study communities and their leaders based on mutual trust and respect. Key points of engagement include regular ‘community entry’ and feedback. Community entry ranges from meetings with civic and traditional leaders to public meetings depending on the nature and sensitivity of research. Annual feedback of HDSS and project findings is to open village meetings; local service providers—health, education, social services and municipality—generally participate, creating a platform for information sharing between these institutions and the community. Selected findings are presented to service providers in the sub-district, local government and provinces.

**What has been measured, and how have the HDSS databases been constructed?**
The primary instrument is a rigorous annual update of resident status and vital events involving every member of the sub-district (Table 3). Well-supervised
fieldworkers visit each household and, following verbal consent, interview the most knowledgeable respondent. They verify existing data and record all new events experienced by each household member—pregnancy outcomes, deaths and in- and out-migrations; this is supplemented by a maternity history for in-migrant women aged 15–54 years. Update rounds involve four teams comprising a supervisor and eight fieldworkers (one dedicated to migration reconciliation); teams work from Geographic Information System-based maps that list every dwelling. Quality control measures include fieldworker self-checks,
cross-checks and supervisor random checks; forms are then sent to a dedicated quality checker before data entry.

Using a locally validated instrument, a dedicated verbal autopsy team (supervisor and four specially trained fieldworkers) interview the closest caregiver of the deceased to establish the probable cause of death. The interview is conducted 1–11 months after a death and then reviewed independently by two medical doctors who assign probable underlying causes.

| Main data item | Specific information |
|----------------|----------------------|
| **Household roster** | |
| Village number; dwelling number | Recorded for each individual |
| Name, surname and gender | Noted if estimate |
| Date of birth | Vital status and where she lives |
| Mother’s identification and location | Vital status and where he lives |
| Father’s identification and location | |
| Relationship of individual to household head | If Mozambican, when arrived in sub-district |
| Nationality/refugee status | Number of months resided in rural household |
| Months resident in last year | Migrant (<6 months in area over past year) |
| Residence status | Permanent (>6 months in area over past year) |
| Visitor (not member of household) | |
| **Education status** | Highest level completed |
| **Pregnancy outcome** | Currently pregnant or not; expected delivery month |
| Antenatal clinic attendance | Non-contributory social grants received (includes old age, child support) |
| Contraceptive use before/after pregnancy | |
| Delivery | |
| Outcome | |
| Duration pregnancy | |
| Infant | Gender, birthweight, breastfeeding and birth registration |
| **Death** | |
| Date of death | Noted if estimate |
| Location of death | Home, clinic, health centre, hospital (+name) and accident site |
| Maternal death | Death during pregnancy or delivery or within 42 days |
| Death registration | |
| **Migration** | Name, national ID |
| Details of in- or out-migrants | Noted if estimate |
| Move date | |
| Place migrated from and to | |
| Main reason for migration | |
| Sector of work for job-related moves | |
| **Maternity History** | Information on each child not listed in household roster |
| Full childbirth history of all women | |
| **Union Status** | Partners’ details, union start/end dates, civil registration, traditional/civil ceremony, reason for union ending |
| Record of all marriages/unions | |
adolescent overweight and obesity (20–25% in older
we find early stunting (one-third of 1–year-olds) and
Central obesity increased from near replacement level.23
Despite a recent slight upswing, fertility remains at
related transitions that have led to marked changes in
Rural South Africa is in the midst of multiple inter-
Key findings and publications
Rural South Africa is in the midst of multiple inter-
How have HDSS databases been constructed?
The database is designed to store and manipulate data
How have HDSS databases been constructed?
The database is designed to store and manipulate data
describing the interrelated life histories of all individuals
and their households. Data are stored in a relational
database, with a schema closely following that
of the 'Reference Demographic Surveillance System
Data Model'.20 The database is implemented on the
Microsoft SQL Server relational database management
platform and hosted in the field site. Integrity constraints,
rules supporting child care and schooling while
having to meet health care and funeral costs.17,37
Pressure on the ‘near-old’—women aged <60 years
and not yet eligible for a pension—can be consider-
whereas self-reported health and quality of
life in pension-eligible older women are markedly im-
proved.39 Infant and child survival are profoundly af-
fected by a mother’s death,22,40 as is child mobility,41
and fostering by women pensioners is clearly advan-
tageous.16–17 Food security among poorer households
remains precarious, with harvesting of natural re-
sources acting as an important buffer against
’shocks’ such as death of a breadwinner.42 Among
the poorest households, reliance on natural resources
is high, no matter what the specific cause of adult
death.26 See the Agincourt website for a listing of
publications:  www.wits.ac.za/academic/health/publi-
Future analysis plans
Ongoing work seeks to deepen understanding of
health, population and social transitions, their effects
at stages along the life course and relationships with
livelihood strategies. Analyses derived largely from the
HDSS database will highlight inequalities and vulner-
able sub-groups to better inform rural health and
development policy.
Current mortality analyses include trends in adult
and child mortality by sex, socio-economic status
and cause-of-death; infant survival both before and
after a mother’s death; the impact of household
structure and socio-economic status on child health
survival; and case definitions and estimates of
the maternal mortality ratio. Investigation of the fer-
tility transition includes analyses of fertility decline
and stall, and patterns of marital and premarital
fertility. We are also comparing fertility patterns
between the local South African population and
| Census year | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|-------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Modules     |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Education   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Labour participation |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Household assets |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Temporary migrations |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Child care grants |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Health care utilization |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Food security |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Adult health |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Unions |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Father support |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| All social grants |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Vital documents |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| National ID numbers |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Cellphone numbers |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Other names |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Status observations |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Chronic cough |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| One-sided weakness |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Pregnancy status |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Epilepsy (seizures) |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |

Household or individual level:
- Target group
- All individuals
- ≥15 years
- All households
- ≥50 years
- All (2003); <5 years (2006)
- Females 12–49 years
- All individuals
- ≥10 years
- ≥15 years
- All individuals

Table 4 Add-on modules and status observations included in update rounds, Agincourt HDSS, 1992–2012
Figure 3  Population pyramids of the Agincourt HDSS population: 1994, 2006 and 2011. (a) de jure population, 1 July 1994; population = 66,405. (b) de jure population, 1 July 2006; population = 72,715. (c) de jure population, 1 July 2011; population = 90,036
former Mozambican refugees. Temporary or circular migration is pervasive in southern Africa. We are examining the association of different migration patterns with fertility outcomes and with mortality trends and causes of death, particularly HIV and non-communicable diseases. Work on the association of child mobility with immunization status is planned. Analyses of natural resource use as a livelihood strategy are ongoing.

The HDSS provides a platform for research across the life course. Examples of analytic work with adolescents include analyses of body composition and other cardiometabolic disease risk factors and levels, and facilitators and barriers to physical activity. In the populations aged \( \geq 15 \) years, we are analysing HIV and non-communicable disease risk factors prevalence, as well as their interactions. In older adults, we are analysing the association between self-reported non-communicable diseases and health care utilization.

Work on linking HDSS data with data from Statistics South Africa is underway to validate national census and vital registration data, especially completeness of population count and coverage of demographic events. We plan to inform policy by evaluating coverage and impact of health and social interventions and provide an early warning system to detect crises among vulnerable populations such as rising food insecurity or sudden peaks in mortality.

Cost-effectiveness will be a feature of intervention evaluations, and HDSS data can be used to model differential costs and benefits before field trials. For example, work to define the burden of epilepsy in disability-adjusted life years will inform cost-effectiveness analyses of potential interventions to address the treatment gap.

In several areas—including epidemiological and demographic transitions, physical and cognitive function in older adults and migration and health—comparative and pooled multi-centre analyses as part of INDEPTH initiatives are a major feature.

### Strengths and weaknesses

The value of the Agincourt HDSS is enhanced by its longevity and context—almost 20 years spanning profound political change and post-abortheid economic development and also the full force of the HIV/AIDS epidemic. This provides a robust sampling frame and research infrastructure to support a range of study designs. Verbal autopsies, on all age groups, have been validated locally using district hospital cases as gold standard.

Further strengths include a university base with a strong graduate training programme; productive partnerships with scientists based in Africa, Asia, UK/Europe and North America; ongoing engagement with village leaders, study communities, local government and non-governmental organizations and public personnel, and increasing collaboration with Statistics South Africa.

Efforts are underway to strengthen the HDSS platform, including real-time electronic data entry, a comprehensive Geographic Information System platform coupled with natural resource and environmental monitoring, and reconciliation of internal migrants. Rural southern Africa is characterized by extensive labour migration that provokes research questions.
and methodological challenges. The Agincourt data system did not initially track migrants within the study site. We now apply a system of ‘migration reconciliation’ (MR) to account for migration and strengthen our analytical database. Undertaking retrospective MR from 2000, we have matched around 70% of internal migrations; with prospective MR, we are achieving >90% of matches. We are also following out-migrants to better understand loss to follow-up in our cohorts. Union status was not recorded until 2007, when we retrospectively collected these data on all—with prospective monitoring since then.

As is the case with many HDSSs, we use a proxy respondent when updating the household roster and vital events. This may reduce the accuracy of some individual-level information (e.g. date of birth) and limits collection of sensitive data such as contraceptive use. We update vital events annually, with the risk of underestimating perinatal and infant mortality, particularly when birth and death occur between consecutive household visits. We limit this possibility by careful probing for pregnancies and births since the last recorded child and since 2006, by asking about pregnancy status of every woman of childbearing age.

As the number and range of projects increase, with multiple follow-up visits and biomarker measurements, we are concerned about overloading households and the potential for refusal rates to increase in the HDSS, as well as in nested studies. Efforts to ensure full documentation of household recruitments to studies are a priority.

Data sharing and collaboration

Fostering effective collaborations, ensuring cross-site compatibility of common variables and optimizing public access to HDSS data are priorities. The Agincourt data website (http://www.agincourt.co.za/DataSection/index.htm) contains full documentation, including questionnaires, data dictionaries and metadata associated with the Agincourt HDSS, as well as an anonymized 10% sample that retains the relational, temporal and data integrity of the full database. Researchers may request a customized relational, temporal and data integrity of the full database help users to prepare the detailed data request needed for a customized extraction.

The MRC/Wits-Agincourt Unit participates in data sharing initiatives that yield datasets that can be freely downloaded. The INDEPTH-WHO SAGE study (Study on global AGEing and adult health) is available on the Global Health Action and INDEPTH websites (http://www.globalhealthaction.net/index.php/gha/rt/suppFiles/5302/6049 and http://www.indepth-network.org/index.php?option=com_content&view=article&id=1215&Itemid=1059). Agincourt data in the INDEPTH-iShare data repository include a subset of core demographic data exported to a common data model and stored in a central database; this will soon be available for download on its own or with similar data from other INDEPTH centres (http://www.indepth-ishare.org/).

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communicable diseases. This poses major challenges for primary health care services, which are ill-equipped to provide quality, integrated long-term care.

- A dual nutritional burden is characterized by marked stunting of children aged <2 years (approaching one-third of children), together with high levels of overweight and obesity in adolescent females (close to 25% by 18 years of age). This indicates elevated risk for metabolic disease in later life and is positively associated with higher socio-economic status.

- In collaboration with Statistics South Africa, the HDSS is used to validate national census and vital registration data and to analyze causal pathways that drive trends seen nationally.

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