Counting births and deaths 2

Are well functioning civil registration and vital statistics systems associated with better health outcomes?

David E Phillips, Carla AbouZahr, Alan D Lopez, Lene Mikkelsen, Don de Savigny, Rafael Lozano, John Wilmoth, Philip W Setel

In this Series paper, we examine whether well functioning civil registration and vital statistics (CRVS) systems are associated with improved population health outcomes. We present a conceptual model connecting CRVS to wellbeing, and describe an ecological association between CRVS and health outcomes. The conceptual model posits that the legal identity that civil registration provides to individuals is key to access entitlements and services. Vital statistics produced by CRVS systems provide essential information for public health policy and prevention. These outcomes benefit individuals and societies, including improved health. We use marginal linear models and lag-lead analysis to measure ecological associations between a composite metric of CRVS performance and three health outcomes. Results are consistent with the conceptual model: improved CRVS performance coincides with improved health outcomes worldwide in a temporally consistent manner. Investment to strengthen CRVS systems is not only an important goal for individuals and societies, but also a development imperative that is good for health.

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This is the second in a **Series** of four papers about counting births and deaths

Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA, USA (D E Phillips BS); **CAZ Consulting, Geneva, Switzerland** (C AbouZahr MSc); **School of Population and Global Health, University of Melbourne, Melbourne, VIC, Australia** (Prof A D Lopez PhD); **LM Consulting, Brisbane, QLD, Australia** (L Mikkelsen PhD); **Swiss Tropical and Public Health Institute, University of Basel, Basel, Switzerland** (Prof D de Savigny PhD); **National Public Health Institute, Mexico City, Mexico** (Prof R Lozano MD); **UN Population Division, New York, NY, USA** (J Wilmoth PhD); **and The Union North America, New York, NY, USA** (P W Setel PhD)

Correspondence to:
David E Phillips, Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA 98121, USA
davidp6@uw.edu

Introduction

One of the reasons many countries make substantial yearly investments in civil registration and vital statistics (CRVS) systems is to obtain crucial health intelligence, among many other benefits. That information can and should be used to deliver better health outcomes for the population. But do these investments lead to improved population health, and if so, through which pathways? Moreover, can this effect be shown to be additional to the well established gains in health from such key drivers as income, education, and equity?

We might expect good CRVS systems to lead to improved health for several reasons. Many societal and individual benefits and entitlements result from birth registration and certification.[1–5] Additionally, registration of births and deaths generates information that has substantial policy utility, especially when age of the mother giving birth, age and sex of the decedent, and underlying cause of death are correctly specified.[2,6] These benefits have been evident from the time that CRVS systems started to be implemented on a routine basis in England and Sweden around the 18th century, where they undoubtedly contributed to health and socio-economic development.[2,7]

Despite increasing recognition that reliable CRVS systems have a central role in monitoring and assessment of aid effectiveness, and despite the inclusion of birth registration among the universal rights of the child 25 years ago, improvement of population coverage with well functioning CRVS systems has been disappointing.[1,8–10] This disappointment might, in part, be because to build a CRVS system is a long-term public policy investment that has not met the short-term information needs of national governments and potential donors. The dearth of empirical research into the global state of CRVS systems, and into the cost-effectiveness, advantages, and limitations of investment in strengthening of CRVS systems, compared with household surveys and facility-based information systems, have all probably contributed to continued inadequate investment.[11,12]

Search strategy and selection criteria

The search strategy included a search of websites of international health and development agencies with mandates covering aspects of civil registration and vital statistics (CRVS), a search of relevant electronic databases (PubMed and Google Scholar), scanning of reference lists from relevant published studies, study of conference proceedings, and direct contacts with technical and in-country experts for references to relevant publications and grey literature. Preference was given to papers with a focus on low-income and middle-income countries and that addressed CRVS in a systemic way. Exclusion criteria were a reference period before 2000 and the production of vital statistics from sources other than the civil registration system.

Key messages

- Well functioning civil registration and vital statistics (CRVS) systems directly benefit individuals and policy, and are independently and statistically significantly associated with better health outcomes
- Ecological analyses show that CRVS performance coincides with good health worldwide, irrespective of income and other factors likely to affect health status
- Well functioning CRVS systems generate crucial information for public health policy, and ensure entitlements and access to services through provision of legal identity to individuals and families
- Greater investment in CRVS systems should be seen as a driver of human development, not only a result of it

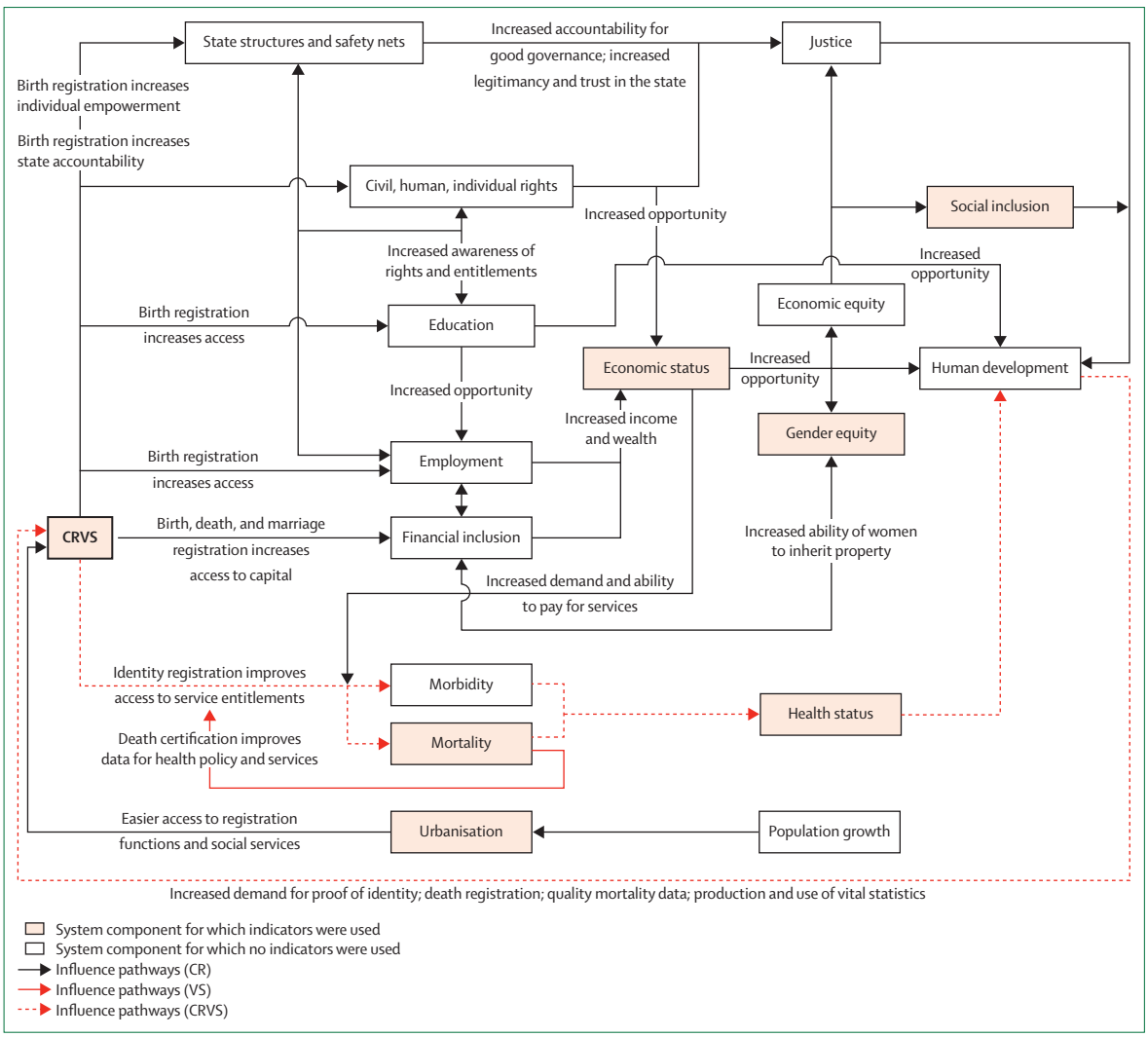

Figure 1: **Pathways of civil registration and vital statistics (CRVS) effects**
CR=civil registration. VS=vital statistics.

In this Series paper, we discuss whether countries that invest to improve their CRVS systems would see returns in terms of improved health. We detail mechanisms by which this improvement in health might occur, and show that well functioning CRVS systems positively correlate with key health indicators, independent of other factors. This association is important new evidence in support of calls for greater, and more urgent, investment to strengthen CRVS systems.[13]

Associations among CRVS, health, and development

On the basis of a synthesis of existing scientific literature and expert knowledge, we identified a system of pathways for a conceptual model describing the outcomes of a well functioning CRVS system, and the benefits those outcomes bring to individuals and societies (figure 1). These pathways connect CRVS systems to social inclusion, equity, and health via identity, entitlements, access, and information.

Figure 1 presents a general schematic of pathways by which CRVS systems might affect, and be affected by, various components of health and social development. Registration of infants at birth enables access to rights, entitlements, and benefits[2,14,15] by establishment of legal identity and family relationships. Proof of identity enables people to claim inheritance, insurance benefits, spousal or partner pension rights, and legal entitlements such as land tenure, and to receive compensation entitlements. Additionally, proof of identity is important to claim nationality either in one's country of birth or that of one's parents.[16] The multifaceted outcomes of strengthened CRVS are central to the World Bank Global Civil Registration and Vital Statistics Scaling Up Investment Plan 2015–2024.[13]

Panel: Civil registration and vital statistics (CRVS) systems, health, and other indicators

Vital statistics performance index

To estimate overall CRVS function (ie, the extent to which a CRVS system accurately and completely registers and certifies vital events), we used a composite indicator known as the vital statistics performance index (VSPI). The VSPI measures quality, completeness, and timeliness of CRVS-derived mortality data on a continuous scale with six empirical indicators.[10,30] These indicators capture distinct dimensions of the strengths and weaknesses of a CRVS system, and are combined in a weighted manner according to an empirical simulation procedure. The VSPI and its methods are described in detail elsewhere.[10,30]

The VSPI is an appropriate metric to assess CRVS system performance because it describes a complex output of a CRVS system, namely mortality statistics.[10] VSPI values have been calculated for all known and available vital statistics data, accounting for 148 countries or territories for each year from 1980 to 2012.[10,30] Of these countries or territories, 144 had available estimates for the outcomes described in table 1.

Outcomes

We examined three health outcomes: healthy life expectancy (HALE), maternal mortality ratio (MMR), and probability of death before age 5 years ($_5q_0$). Each outcome was estimated at the country-year level as part of the Global Burden of Disease study 2010 (table 2).[31–33]

The three outcomes were selected either to represent global health and development priorities (eg, millennium development goals 4 and 5) or to simultaneously capture mortality and morbidity in populations (eg, HALE). Unlike other potential outcomes of interest, health outcomes are arguably exogenous to CRVS performance. Consider, for example, social inclusion (a non-health outcome) as a possible outcome variable. Although improved CRVS might lead to more social inclusion, an effect in the reverse direction clearly exists—ie, more social inclusion will probably contribute to improved registration practices. Health outcomes, by contrast, do not have this endogeneity; no clear mechanism is known by which better population health leads to improved CRVS. For these reasons, we restricted this analysis to health outcomes.

Covariates

We controlled for four confounding factors: income, urban development, health system strength, and contraceptive prevalence. These factors were measured by gross domestic product (GDP) per capita, proportion of population in urban areas, a composite health system access measure, and contraceptive prevalence (table 3). Covariates were estimated at the country-year level by various research groups.[34–36]

These covariates represent factors that are most likely to confound the association between well functioning CRVS systems and their outcomes, and factors that do so through unique exogenous mechanisms. For example, we control for GDP per capita because wealthy countries have increased average health and are likely to have and maintain good-quality CRVS systems.[1,34,37] We control for urbanisation because health and administrative facilities are concentrated in urban areas, and registration of births and deaths and cause of death certification, are usually more complete in urban areas.[38] However, health systems and delivery of health services might vary among societies with similar levels of urbanisation. Therefore, we use a composite indicator termed health system access as an additional control variable. Finally, we control for contraceptive prevalence. Use of contraception improves population health outcomes such as maternal and child mortality because it enables effective birth spacing.[39–41] Evidence suggests that contraceptive use is a good proxy for female autonomy, mobility, and decision-making power, which collectively are expected to fuel demand for, and use of, birth registration.[42–44]

	Category	Example countries
≥0·85	Very high	Finland, UK, Australia, Cuba
0·70–0·84	High	South Africa, Colombia, Malaysia
0·50–0·69	Medium	Dominican Republic, Philippines, Iran
0·25–0·49	Low	Belarus, Brunei, Fiji
<0·25	Very low	Pakistan, Botswana, Bolivia

Table 1: **Vital Statistics Performance Index (VSPI) values, categories, and example countries**

Civil registration has well documented links to legal entitlements and access to services.[8] Although registration of birth does not guarantee access to education, health, social protection, or citizen participation, without a birth certificate those fundamental rights can be beyond reach.[8] People—especially children—with registration documentation are less vulnerable to statelessness and associated risks.[17] Proof of age enables prosecution of perpetrators of crimes against children, such as child trafficking, sexual offences, early recruitment into the armed forces, child marriage, and child labour. Proof of birthplace and parentage directly enables citizenship, and might be fundamental to efforts to make health coverage universal.[18] Availability of legal proof of marriage and divorce is especially important for female heads of household and the families they support. For example, proof of marriage enables access to widows' pensions or broader public services, such as education and health. Additionally, proof of marriage can help women to obtain nationality or at least residency in a country and, in some societies, protect their rights of access to, and guardianship of, children.[19]

Through entitlements and access, non-discriminatory civil registration can promote social inclusion and contribute to reduced gender and economic inequalities. Individuals with legal identities can fully participate in the modern economy, open bank accounts, take on loans, purchase property, and invest in businesses. Possession

of a birth certificate can be a determining factor to break the cycle of poverty.[8] A citizenry of individuals with legal identities is likewise more likely to be aware of its rights and entitlements, to hold authorities to account, and to participate in political processes, vote in elections, and stand for electoral office. In short, birth registration makes individuals more visible, and the state more accountable for provision of health, education, other services, safety nets, and legal protection.[20]

The vital statistics produced by civil registration provide planners with essential epidemiological intelligence to promote and protect population health. These data guide policy reforms designed to reduce disease burden, and can help to improve allocative efficiency and effectiveness of health systems. Two examples have been the role of vital statistics in stimulation of epidemiological research into causes of increasing lung cancer mortality in Britain and other countries immediately after the Second World War,[21–24] and in assessment of population-level interventions against road traffic injuries two decades later.[25,26] In both cases, the extent, pattern, and trend of mortality was discernible from vital statistics, as was the effect of subsequent population-level interventions. Arguably, reductions in premature death after introduction of policies limiting population exposure to hazards such as tobacco and drink driving would have taken much longer without evidence that well functioning CRVS systems provided.

These benefits probably emerge over differing timescales, which are not depicted in figure 1. For example, marriage certification, death registration, and improved cause-of-death certification could begin to show benefits almost immediately. Likewise, evidence suggests that birth registration provides short-term benefits to individuals and societies. Two notable examples are that children registered at birth are more likely to be immunised,[27] and that registered children can be more easily identified and protected when separated from their parents—a benefit that is especially important during humanitarian emergencies.[28,29] Other positive effects of birth registration, however, might take several years to materialise at the individual level. Similarly, increased access to health services, financial inclusion, and use of protected entitlements might gradually emerge over years or even decades. The confluence of all of these benefits at individual and societal levels might reasonably be expected to lead to sustainable improvements in human development, owing to increased opportunity for individuals to participate fully in society and generation of health intelligence to reduce risks to health.

Measurement of the association between CRVS performance and health outcomes

If the hypothesised health benefits of CRVS are true, then association between CRVS performance and health outcomes should be measurable with appropriate metrics. However, pragmatic constraints, limitations of available data, and difficulties in identification of valid measurement instruments rule out strong analytic designs for causal inference, such as quasi-experimental approaches or instrumental variables to assess the hypothesised relation. Measurement is thus restricted to observational data analysis at the population level, which might have various sources of bias.

We used a composite metric of national CRVS performance known as the vital statistics performance index (VSPI),[30] and compared it with national estimates of healthy life expectancy (HALE), maternal mortality ratio (MMR), and child mortality risk ($_5q_0$),[31–33] with controls for confounding (panel).[34–36]

	Definition	Mean (SD)	Source
Healthy life expectancy (HALE)	Average expected duration of life in good health, taking into account mortality and disability	62·50 (4·67)	Salomon et al (2012)[31]
Maternal mortality ratio (MMR)	Number of pregnancy-related deaths per 100 000 livebirths	30·20 (45·13)	Lozano et al (2012)[32]
Child mortality risk ($_5q_0$)	Probability of death before age 5 years	0·029 (0·029)	Wang et al (2012)[33]

Table 2: **Health outcomes analysed**

	Definition	Mean (SD)	Source
Log-GDP per capita	Market value (in international dollars) of all officially recognised final goods and services produced within a country in a given period of time, divided by the total population	9·11 (0·94)	James et al (2012)[34]
Urbanisation	Proportion of population residing in urban areas	0·62 (0·20)	UN World Urbanisation Prospects[35]
Health system access	Principal components analysis of coverage of hospital beds, antenatal care (one and four visits), skilled birth attendance, in-facility delivery, tetanus toxoid vaccine, diphtheria-tetanus-pertussis vaccine, and measles vaccine	7·92 (4·04)	Global Burden of Diseases 2013[36]
Total contraceptive prevalence	Proportion of women aged 15–49 years who use, or whose partner uses, any method of contraception	0·44 (0·14)	Global Burden of Diseases 2013[36]

GDP=gross domestic product.

Table 3: **Covariates**

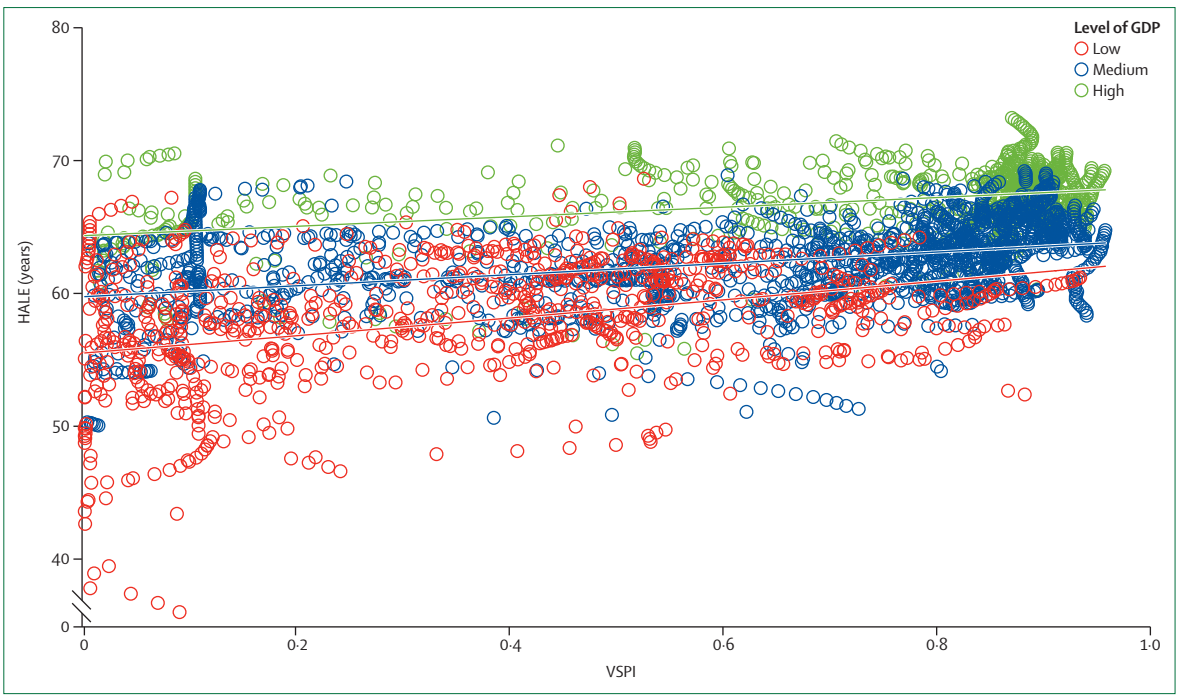

Figure 2: **Healthy life expectancy (HALE) compared with the vital statistics performance index (VSPI), stratified by gross domestic product (GDP)**

	Coefficient (95% CI)	p value
Healthy life expectancy (HALE)		
VSPI	1·044 (1·020–1·068)	0·000
Health system access	1·003 (1·001–1·006)	0·004
GDP (per capita)	1·026 (1·016–1·036)	0·000
Total contraceptive prevalence	1·091 (1·014–1·173)	0·019
Urban population (proportion)	1·059 (1·018–1·102)	0·005
Maternal mortality ratio (MMR)		
VSPI	0·721 (0·508–1·023)	0·067
Health system access	0·872 (0·845–0·900)	0·000
GDP (per capita)	0·727 (0·602–0·877)	0·001
Total contraceptive prevalence	0·305 (0·116–0·801)	0·016
Urban population (proportion)	1·039 (0·554–1·951)	0·904
Child mortality risk ($_5q_0$)		
VSPI	0·418 (0·367–0·470)	0·002
Health system access	0·475 (0·470–0·480)	0·000
GDP (per capita)	0·419 (0·392–0·446)	0·000
Total contraceptive prevalence	0·284 (0·180–0·418)	0·002
Urban population (proportion)	0·491 (0·384–0·600)	0·879

VSPI=vital statistics performance index. GDP=gross domestic product. Original outcome variables were log-transformed (logit for $_5q_0$); coefficients and CIs have been back-transformed. Year-specific and overall intercepts are not shown.

Table 4: **Regression results**

A modest, but robust and consistent correlation exists between VSPI and health indicators across country-years. HALE is high and $_5q_0$ and MMR are low among countries with improved CRVS performance. The ecological association between the VSPI and HALE is shown in figure 2. On average, HALE was estimated to increase by 0·044% with each unit increase in VSPI on a 100-point scale (coefficient 1·044 on a 0–1 scale; 95% CI 1·020–1·068; p<0·0005). The regression indicates that if worldwide CRVS performance was high (0·9) rather than at its worldwide average based on the 144 countries or territories with available data (0·591), average HALE would increase by nearly 1 year (63·1 years *vs* 62·3 years).[30] MMR and $_5q_0$ are similarly associated with VSPI. Countries with high VSPI values have low MMR (0·721; 95% CI 0·508–1·023; p=0·067) and $_5q_0$ values (0·418; 0·367–0·470; p=0·002). The model results are presented in more detail in table 4.

The association between VSPI and health indicators is not likely to be due to confounding. Marginal regression models were used to measure the ecological association between VSPI and health outcomes and to control for confounding (see appendix for a more detailed description of the modelling strategy). Controlling for the four covariates, HALE is on average high, and $_5q_0$ and MMR low, among countries with high VSPI values. Figure 2 shows the persistence of the association among countries stratified into low, medium, and high gross domestic product (GDP) (according to the 25th and 75th percentiles of GDP), showing that the ecological association exists irrespective of GDP. Statistical analyses show a similar trend when the full gradient of GDP, other covariates, and time-related confounding are accounted for (table 4).

See Online for appendix

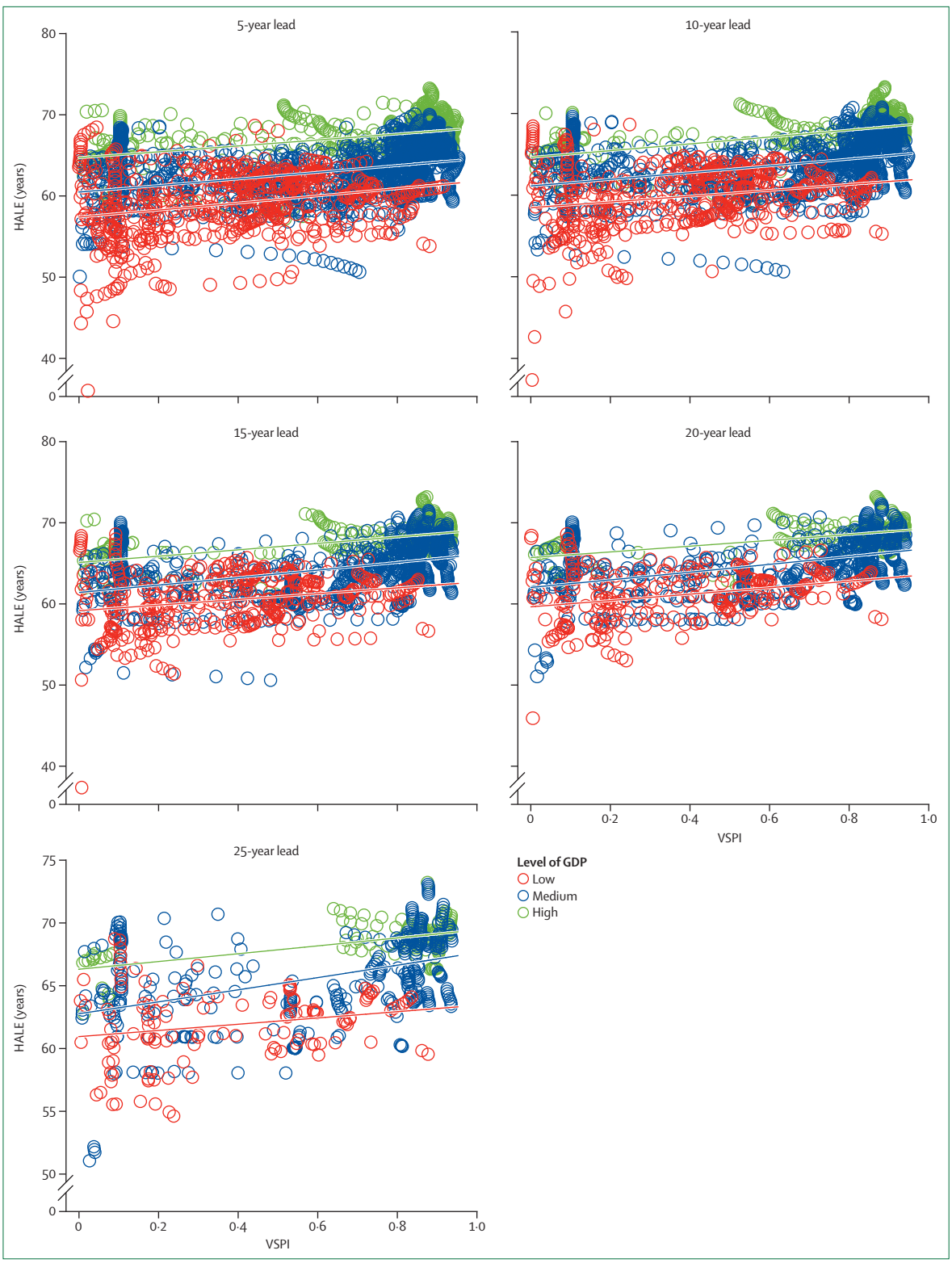

Figure 3: 5-year, 10-year, 15-year, 20-year, and 25-year lead of healthy life expectancy (HALE) compared with vital statistics performance index (VSPI), stratified by gross domestic product (GDP)

Lag-lead analysis

A strong association exists between CRVS performance and delayed health outcomes. Improved CRVS systems are expected to affect health and development gradually, in addition to their more immediate benefits. This gradual effect is expected to produce a measurable ecological association with the leads, or future values, of the outcomes relative to VSPI (figure 3). Irrespective of GDP, VSPI is closely associated with HALE in the future (table 5). A similarly strong association exists between future values of $_5q_0$ and VSPI. The future values of MMR, however, are not associated with VSPI.

The lag-lead analysis is likewise generally consistent with the conceptual model in the reverse direction (ie, when delayed VSPI is used instead of delayed outcomes). A mechanism by which CRVS could be associated with previous health outcomes would be difficult to imagine according to the pathways specified in our conceptual model. Consistent with this idea, future CRVS performance was not statistically significantly associated with past health outcomes in most cases, although the 5-year lead of the VSPI was associated with HALE and $_5q_0$ and the 10-year lead was associated with HALE (table 5).

These ecological analyses show that CRVS performance coincides with good health worldwide, irrespective of income and other factors. These associations occur in patterns that are expected according to the theory that population health status is improved when registration systems are strong, and that improved registration systems precede observable improvements in health.

	Health outcomes		CRVS performance	
	Coefficient (95% CI)	p value	Coefficient (95% CI)	p value
Healthy life expectancy (HALE)				
5-year	1·038 (1·014–1·063)	0·002	1·039 (1·012–1·068)	0·005
10-year	1·040 (1·015–1·066)	0·002	1·033 (1·002–1·065)	0·035
15-year	1·047 (1·020–1·074)	0·000	1·030 (0·997–1·065)	0·077
20-year	1·052 (1·024–1·081)	0·000	1·028 (0·989–1·068)	0·156
25-year	1·048 (1·018–1·078)	0·002	1·028 (0·989–1·068)	0·168
Maternal mortality ratio (MMR)				
5-year	0·774 (0·542–1·107)	0·16	0·760 (0·508–1·137)	0·182
10-year	0·787 (0·547–1·132)	0·196	0·821 (0·533–1·264)	0·371
15-year	0·838 (0·570–1·234)	0·371	0·934 (0·576–1·514)	0·780
20-year	0·911 (0·602–1·379)	0·659	0·985 (0·558–1·740)	0·960
25-year	1·011 (0·665–1·537)	0·958	0·982 (0·505–1·907)	0·956
Child mortality risk ($_5q_0$)				
5-year	0·425 (0·367–0·485)	0·015	0·421 (0·358–0·486)	0·018
10-year	0·424 (0·363–0·488)	0·020	0·429 (0·356–0·504)	0·064
15-year	0·413 (0·349–0·480)	0·011	0·439 (0·356–0·525)	0·161
20-year	0·410 (0·343–0·480)	0·013	0·452 (0·357–0·551)	0·344
25-year	0·435 (0·363–0·509)	0·086	0·447 (0·349–0·548)	0·304

Original outcome variables were log-transformed (logit for $_5q_0$); coefficients and CIs have been back-transformed. Year-specific and overall intercepts, coefficients for covariates not shown. *Lead refers to future values of the dependent variable (HALE, MMR, or $_5q_0$) in the left-hand columns and the independent variable (CRVS performance) in the righ-hand columns.

Table 5: **Regression results for 5-year, 10-year, 15-year, 20-year, and 25-year leads* of health outcomes and civil registration and vital statistics (CRVS) performance**

Role of CRVS systems in population health

On the basis of CRVS data and health outcome measurements for 144 countries during the past 33 years, we show that well performing CRVS systems consistently co-occur with improved health, irrespective of a population's wealth, level of urbanisation, health system coverage, or contraceptive prevalence. We likewise expect CRVS performance to have a measurable association with future health outcomes, and we show that ecological data are consistent with these expectations.

Study limitations

Several limitations will need to be considered. First, VSPI is based on mortality registration alone, so our measure of CRVS performance might be underestimated in countries with systems that successfully register births but not deaths (eg, Botswana). If the same countries have poorer than expected health compared with other countries in this analysis, the statistical associations might be overestimated. Second, measurement error might weaken the representativeness of controls used in this analysis, and thus residual confounding might be a concern. However, we did sensitivity analyses to show that measurement error in the outcomes is less of a concern. The same health outcomes measured with different methods (UN estimates of $_5q_0$ and life expectancy at birth[45]) yielded almost identical regression coefficients (appendix). Third, unmeasured confounding, such as legal respect for fundamental human rights, could potentially explain the ecological association. Many of the strongest drivers of population health were not included in this analysis in the interest of including only unique covariates that simultaneously affect CRVS systems and health. Other covariates, such as population-level educational attainment, represent country variation that we believe is adequately captured by the existing covariates. Fourth, countries in this analysis were modelled as independent of one another, although they might not be (eg, spatial correlation of neighbouring countries was not considered). This assumption could have led to underestimates of uncertainty. Fifth, the outcome variables in the analysis are model-based estimates, and the models that produced them used (to some extent) vital statistics as an input. The possible endogeneity presented by this circular relation might bias our estimates, although theoretically will affect only uncertainty about outcomes among countries with low CRVS performance. We tested sensitivity to this potential problem (appendix) and showed that, when only the subset of country-years with reliable CRVS data are included (in this case, observations in the upper

third of VSPI values), the association is generally strong. Last, not every country in the world had data available for analysis. The countries without available data might be considered informative censoring because they probably have characteristics in common. If such countries are negatively or inconclusively affected by CRVS system performance, then the regression models presented here might not be as generalisable worldwide as our sample implies. Although this limitation is a concern, it has no effect on the validity of the association within the sample, and testing it is beyond the scope of this analysis.

The ecological evidence is not unequivocally consistent with theory. Sensitivity analyses were done to investigate the relation of CRVS performance with other health outcomes. Although in nearly all cases the results were as expected, one apparent inconsistency is worth noting. Adult mortality (one alternative health outcome) was not statistically significantly associated with VSPI after controlling for covariates. Although further research is needed to explain the inconsistency, we note that adult mortality had no measurable association with health service access or contraceptive prevalence. This result was not recorded for any other outcome. One possible explanation is that the mechanisms through which these factors affect overall levels of adult mortality are sufficiently explained by the other covariates, and that their redundant appearance in the model detracts from the association that would otherwise be measured with VSPI. Some empirical evidence supports this explanation: the coefficient on VSPI changed only slightly with the exclusion of non-significant covariates, but the p value decreased substantially (coefficient 0·458; 95% CI 0·416–0·501; p=0·055).

Evidence from the lag-lead analysis, although compellingly supportive of an association between CRVS and health outcomes, is not wholly consistent. Our results for future MMR and short-term leads of VSPI (compared with past HALE and ${}_5q_0$) were contrary to the conceptual model. We can only speculate about the meaning of these inconsistencies. The observation that future MMR was not associated with previous VSPI implies that additional complexity of non-health system factors exists within this specific pathway, and should be investigated further. With regard to past HALE and ${}_5q_0$, development of a CRVS system might precede our ability to measure its performance. Therefore, the short-term association between future VSPI and past HALE or ${}_5q_0$ might be consistent with our conceptual model.

Statistical analysis of this nature should be interpreted appropriately. The regression is not meant to explain most variation in health outcomes, and should not be interpreted as doing so. The objective is to investigate whether an unconfounded association exists between CRVS performance and health outcomes to establish empirical evidence for the associations we posit. Even so, the analysis described above has limitations. Although we do not claim to have established causal relations between CRVS and health outcomes statistically, we believe that our conceptual model realistically describes the mechanisms through which well functioning CRVS systems can contribute to health.

Conclusion

Limitations notwithstanding, our analysis contributes important new evidence to support the hypothesis that well functioning CRVS systems not only have direct benefits for individuals and for policy-making processes that use vital statistics, but also contribute to improved population health outcomes. In addition to the crucial value of registration of vital events for promotion of human rights and sustainable development, we suggest that action to strengthen CRVS should not be merely a characteristic of development efforts, but rather a key driver of them. Through improved CRVS systems, people making resource allocation decisions have the opportunity to simultaneously create policy-essential data and enhance individual and collective wellbeing. Countries, regional development partners, and civil society alike should thus derive further motivation from knowledge that strengthening of CRVS systems is not only an important goal for individuals and societies, but is also good for health and development.

Contributors

CAZ and ADL conceived the idea for the series and developed the outline for the series, including this paper. DEP and PWS prepared the first draft of the paper on the basis of initial inputs from the rest of the group. DEP did the statistical analyses. All authors provided feedback, additional and new inputs and suggestions, and reviewed the final manuscript.

Declaration of interests

We declare no competing interests. The views expressed herein are those of the authors and do not necessarily reflect the views of the United Nations.

References

1 Setel PW, Macfarlane SB, Szreter S, et al, and the Monitoring of Vital Events (MoVE) writing group. A scandal of invisibility: making everyone count by counting everyone. *Lancet* 2007; **370:** 1569–77.

2 Szreter S. The right of registration: development, identity registration, and social security—a historical perspective. *World Dev* 2007; **35:** 67–86.

3 UNICEF, IRC. Birth registration: right from the start. *Innocenti Digest* 2002; **9:** 1–32.

4 Todres J. Birth Registration: an essential first step toward ensuring the rights of all children. *Hum Rights Brief* 2003; **10:** 32–35.

5 Dow U. Birth registration: the "first" right. In: The progress of nations. New York, USA: UNICEF, 1998. 5–11.

6 Mathers CD, Fat DM, Inoue M, Rao C, Lopez AD. Counting the dead and what they died from: an assessment of the global status of cause of death data. *Bull World Health Organ* 2005; **83:** 171–77.

7 Ruzicka L, Wunsch G, Kane P, eds. Differential mortality. Methodological issues and biosocial factors. Oxford, UK: Oxford University Press, 1989.

8 Harbitz M, del Carmen Tamargo M. The significance of legal identity in situations of poverty and social exclusion: the link between gender, ethnicity, and legal identity. New York, USA: Inter-American Development Bank, 2009.

9 Mahapatra P, Shibuya K, Lopez AD, et al, and the Monitoring Vital Events (MoVE) writing group. Civil registration systems and vital statistics: successes and missed opportunities. *Lancet* 2007; **370:** 1653–63.

10 Mikkelsen L, Phillips DE, AbouZahr C, et al. A global assessment of civil registration and vital statistics systems: monitoring data quality and progress. *Lancet* 2015; published online May 11. http://dx.doi.org/10.1016/S0140-6736(15)60171-4.

11 Rommelmann V, Setel PW, Hemed Y, et al. Cost and results of information systems for health and poverty indicators in the United Republic of Tanzania. *Bull World Health Organ* 2005; **83:** 569–77.

12 Jimenez-Soto E, Hodge A, Nguyen K, Dettrick Z, Lopez AD. A framework for the economic analysis of data collection methods for vital statistics. *PLoS One* 2014; **9:** e106234.

13 World Bank, WHO. Global civil registration and vital statistics. Scaling up investment plan 2015–2024. Washington, DC: World Bank, 2014.

14 Torpey JC. Documenting individual identity: the development of state practices in the modern world. Princeton, USA: Princeton University Press, 2001.

15 Linder FE, Moriyama IM. Improving civil registration. Bethesda, USA: International Institute for Vital Registration and Statistics, 1984.

16 Cooper E. Challenges and opportunities in inheritance rights in Uganda. London, UK: Chronic Poverty Research Centre, 2011.

17 Rose LL. Children's property and inheritance rights and their livelihoods: the context of HIV and AIDS in Southern and East Africa. Rome, Italy: Food And Agriculture Organization of the United Nations, 2006.

18 O'Connell T, Rasanathan K, Chopra M. What does universal health coverage mean? *Lancet* 2014; **383:** 277–79.

19 Sumner C, Lindsey T. Courting reform: Indonesia's islamic courts and justice for the poor. *Int J Court Adm* 2011; **4:** 3–16.

20 Boekle-Giuffrida B, Harbitz M. Democratic governance, citizenship and legal identity—linking theoretical discussion and operational reality. Working Paper. Washington, DC: Inter-American Development Bank, 2009.

21 Doll R, Peto R. The causes of cancer: quantitative estimates of avoidable risks of cancer in the United States today. *J Natl Cancer Inst* 1981; **66:** 1191–308.

22 Thun MJ, Carter BD, Feskanich D, et al. 50-year trends in smoking-related mortality in the United States. *N Engl J Med* 2013; **368:** 351–64.

23 Peto R, Lopez AD, Boreham J, Thun M, Heath C Jr. Mortality from tobacco in developed countries: indirect estimation from national vital statistics. *Lancet* 1992; **339:** 1268–78.

24 Davis DL, Hoel D, Fox J, Lopez AD. International trends in cancer mortality in France, West Germany, Italy, Japan, England and Wales, and the United States. *Ann N Y Acad Sci* 1990; **609:** 5–48.

25 Harvey AC, Durbin J. The effects of seat belt legislation on British road casualties: a case study in structural time series modelling. *J R Stat Soc Ser Gen* 1986; **149:** 187–227.

26 Nakahara S, Nakamura Y, Ichikawa M, Wakai S. Relation between increased numbers of safe playing areas and decreased vehicle related child mortality rates in Japan from 1970 to 1985: a trend analysis. *J Epidemiol Community Health* 2004; **58:** 976–81.

27 Corbacho A, Brito S, Osorio R. Does birth under-registration reduce childhood immunization? Evidence from the Dominican Republic. Washington, DC, USA: Inter-American Development Bank, 2013.

28 De Silva N. Protecting the rights of the tsunami victims: the Sri Lanka experience. Kolkata, India: Mahanirban Calcutta Research Group, 2010.

29 Innocenti Research Centre. Birth Registration and Armed Conflict. Florence, Italy: UNICEF, 2007.

30 Phillips DE, Lozano R, Naghavi M, et al. A composite metric for assessing data on mortality and causes of death: the vital statistics performance index. *Popul Health Metr* 2014; **12:** 14.

31 Salomon JA, Wang H, Freeman MK, et al. Healthy life expectancy for 187 countries, 1990–2010: a systematic analysis for the Global Burden Disease Study 2010. *Lancet* 2012; **380:** 2144–62.

32 Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380:** 2095–128.

33 Wang H, Dwyer-Lindgren L, Lofgren KT, et al. Age-specific and sex-specific mortality in 187 countries, 1970–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380:** 2071–94.

34 James SL, Gubbins P, Murray CJ, Gakidou E. Developing a comprehensive time series of GDP per capita for 210 countries from 1950 to 2015. *Popul Health Metr* 2012; **10:** 12.

35 United Nations Department of Economic and Social Affairs/Population Division. World urbanization prospects, the 2011 revision. New York, USA: United Nations, 2012.

36 GBD 2013 Mortality and Causes of Death Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014; **385:** 117–171.

37 WHO. Macroeconomics and health: investing in health for economic development. Geneva: World Health Organization, 2001.

38 Omran AR. The epidemiologic transition. A theory of the epidemiology of population change. *Milbank Mem Fund Q* 1971; **49:** 509–38.

39 Ahmed S, Mosley WH. Simultaneity in the use of maternal–child health care and contraceptives: evidence from developing countries. *Demography* 2002; **39:** 75–93.

40 DaVanzo J, Hale L, Razzaque A, Rahman M. The effects of pregnancy spacing on infant and child mortality in Matlab, Bangladesh: how they vary by the type of pregnancy outcome that began the interval. *Popul Stud (Camb)* 2008; **62:** 131–54.

41 Trussell J, Pebley AR. The potential impact of changes in fertility on infant, child, and maternal mortality. *Stud Fam Plann* 1984; **15:** 267–80.

42 Al Riyami A, Afifi M, Mabry RM. Women's autonomy, education and employment in Oman and their influence on contraceptive use. *Reprod Health Matters* 2004; **12:** 144–54.

43 Mumtaz Z, Salway S. 'I never go anywhere': extricating the links between women's mobility and uptake of reproductive health services in Pakistan. *Soc Sci Med* 2005; **60:** 1751–65.

44 Saleem S, Bobak M. Women's autonomy, education and contraception use in Pakistan: a national study. *Reprod Health* 2005; **2:** 8.

45 United Nations Development Program. Human Development Report 2013. The rise of the south: human progress in a diverse world [Internet]. New York, USA: United Nations, 2013. http://hdr.undp.org/en/media/HDR_2013_EN_complete.pdf (accessed March 9, 2015).