HRH in Africa: A New Look at the Crisis

Needs-Based Estimates for the Health Workforce
(Chapter 2)

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The health workforce stands in the center of health systems. Medical equipment, supplies, facilities, and medication will be underutilized, without a trained workforce that is accessible to the community it serves. Because of limited resources in Sub-Saharan Africa, it is important to accurately estimate the number of health workers required to meet the region's health care needs, as this will help governments and donors make prudent health systems spending decisions. Health workforce requirements can be estimated using a needs-based approach, by estimating the extent that health care needs are being met by the existing health workforce. This chapter uses the needs-based approach to empirically estimate the health worker requirements to meet various health care needs in 18 countries in Sub-Saharan Africa. Health worker requirements vary significantly, depending on the health care need used to generate the requirement, and the population distribution of individual countries.

A Conceptual Needs-Based Approach to Estimating Health Workforce Requirements

A country's health workforce is critical to the well-being of its health system and its people. Well-trained cadres of health workers are essential to improving the health status of a country, and to maximizing the effectiveness of its health care system. For health care planners and government officials, estimating the required number of health workers for specific health needs is an important component of strengthening health systems and achieving the health-related United Nations Millennium Development Goals (Crisp and Gawanas, 2008). This chapter presents a conceptual framework, termed the Needs-Based Approach, to estimate the human resources in health (HRH) requirements (specifically doctors, nurses, and midwives) for various health care measures, and empirically applies the framework to 53 countries, including 18 in Sub-Saharan Africa.

Estimates of health worker needs-based requirements are developed by showing the relationship between a country's existing health workforce to specific, sought-after health care service utilization levels and health outcome goals, which are proxy measures for need. This approach begins with the selection of health care services or outcome measures. Examples include the proportion of births attended by a skilled health worker, breast cancer screening rates, infant and maternal mortality rates, and burden of disease rates among conditions such as HIV/AIDS, tuberculosis, and malaria. The number of health workers required to achieve particular levels on the selected measures is then estimated using data from multiple countries, or from multiple regions within a country.

In an important example of this approach, the World Health Organization (WHO) in its report, *Working Together for Health: The World Health Report 2006,* found that countries that did not have at least 2.28 doctors, nurses and midwives per 1,000 residents were, on average, unable to achieve an 80 percent coverage rate of births by a skilled birth attendant (WHO, 2006). WHO selected the 80 percent threshold partly because it wanted to set a minimum desired coverage level, and partly because the benefit of additional health workers on the birth coverage rate began to diminish near this threshold.

This chapter improves upon the WHO method in two important ways. First, WHO estimated the number of required health workers using a single health care measure, birth attendance by a health worker. This chapter examines multiple health care measures, to show how the number of workers required to achieve a specific goal is sensitive to the measure being examined. Second, the relationship between health workers and health measures will vary across countries because of worker productivity differences. These differences stem from countries having different health care systems, financing mechanisms, worker training, geographical characteristics, and population distributions, as well as differences among other factors such as medical facilities, equipment, supplies and pharmaceuticals. WHO did not account for these in its analysis.

To demonstrate this more nuanced, differentiated approach, the analysis in this chapter includes two country-level population distribution factors, to show how HRH requirements will vary by country. An extension of this approach would include the other factors listed above that affect worker productivity.

Application of the Needs-Based Approach

The needs-based approach is applied to 53 countries, including 18 in Sub-Saharan Africa, using data from the World Health Survey (WHS) 2002. WHO sponsored this survey, which randomly sampled approximately 4,000 adults per country. Respondents were asked a series of questions about their own and family members' health status, health care services utilization and expenditures, as well as demographic information, including whether the respondent lived in an urban or rural setting (see Appendix for more detail). Health workforce supply estimates were from *Working Together for Health: The World Health Report 2006* (WHO, 2006).[1] To be consistent with WHO (2006), the analysis defined health workers as including doctors, nurses, and midwives. Country population estimates were obtained from the U.S. Census Bureau's 2002 Global Population Profile.

Table 1 lists country-level statistics for all 53 countries and for the 18 Sub-Saharan African countries; the statistics are based on a country being the unit of analysis, and were not weighted for population differences (consistent with WHO, 2006). The statistics included measures on health care service utilization, health outcomes, the health workforce, and the population distribution. For example, for the full sample of 53 countries, the country-level average for births attended by a health worker was 83 percent. Except for vaccinations, in general, health care service utilization was lower in Sub-Saharan Africa than for the full sample. The result was similar for the heath workforce variables; for all 53 countries, the average was 4.25 health workers per 1,000 population, versus the Sub-Saharan African average of 1.73 health workers per 1,000 population.

Table 1: Country-Level Health and Population Distribution Statistics

	All Countries (n=53)		Sub-Saharan African Countries (n=18)	
	Mean	**Std Dev**	**Mean**	**Std Dev**
Health Care Services				
1. Birth attended by health worker (1 yes, 0 no) [a]	0.83	0.23	0.74	0.23
2. Birth attended by doctor (1 yes, 0 no) [a]	0.67	0.34	0.46	0.30
3. Birth attended by nurse or midwife (1 yes, 0 no) [a]	0.77	0.27	0.73	0.27
4. Pelvic examination <3 years (1 yes, 0 no) [b]	0.37	0.28	0.17	0.14
5. Pap smear test <3 years (1 yes, 0 no) [b]	0.55	0.27	0.44	0.14
6. Mammography <3 years (1 yes, 0 no) [c]	0.16	0.17	0.05	0.04
7. HIV testing offered when pregnant (1 yes, 0 no) [d]	0.25	0.25	0.19	0.16
8. Received healthcare when needed it (1 yes, 0 no)	0.96	0.04	0.94	0.04
9. Received any vaccination (1 yes, 0 no) [e]	0.71	0.20	0.76	0.11
10. Received DPT vaccination (1 yes, 0 no) [e]	0.91	0.09	0.93	0.05
11. Received measles vaccination (1 yes, 0 no) [e]	0.77	0.14	0.82	0.10
12. Received vitamin A capsule or similar supplement (1 yes, 0 no) [e]	0.46	0.25	0.61	0.21
Health Outcomes				
13. Health rating (1 very good or good, 0 otherwise)	0.60	0.14	0.64	0.11
14. Health satisfaction (1 very satisfied or satisfied, 0 otherwise)	0.61	0.13	0.59	0.14
Health Workforce				
Doctors per 1,000 population	1.30	1.34	0.21	0.27
Nurses and midwives per 1,000 population	2.95	2.84	1.52	1.68
Health workers per 1,000 population	4.25	3.98	1.73	1.85
Population Distribution				
Land (square km) per capita [f]	0.04	0.08	0.08	0.12
Urban (% of total population)	49.8	24.5	38.0	21.3

[a] Asked of women who were pregnant in the last 5 years (since January 1998)
[b] Asked of women aged 18-69
[c] Asked of women aged 40-69
[d] Asked of women who were pregnant in the last 2 years (since January 2001)
[e] Asked of children under 5 years old
[f] Sources: CIA's The World Factbook (land area); U.S. Census Bureau, Global Population Profile: 2002 (population)
DPT: diphtheria, pertussis (whooping cough) and tetanus
Std Dev: standard deviation
Source: World Health Survey 2002 (except where noted)

To examine the relationship between the size of the health workforce and measures of health care services utilization and outcomes, 12 health care services and two health outcomes were analyzed (see Table 1). The basic analysis included the number of health workers per 1,000 population, and further analyses included the percentage of the country's population living in an urban area and the country's land area per capita, because these characteristics may be related to an individual's access to health care services (see Appendix for more detail on methods). The results illustrate which health care services and health outcomes were statistically related to the size and composition of the health workforce, and whether the required number of health workers varied, based on a country's population distribution.

Relationship between Health Workers and Health Measures

The needs-based analysis determined that the number of health workers per 1,000 population in a country was positively related to many of the health care service measures; these included birth attended by a health worker (either a doctor, nurse, or midwife), birth attended by a doctor, birth attended by a nurse or midwife, a pelvic examination in the last three years, a Pap smear test in the last three years, a mammography in the last three years, HIV testing offered during pregnancy, and health care being received when needed (see Table A1 and Table A2 in Appendix A). On the other hand, no relationship was found between the number of health workers and whether a child received vaccinations.[2]

To illustrate one specific health service relationship, Figure 1 shows the percentage of births attended by a health worker as a function of the number of health workers per 1,000 population, for all 53 countries analyzed. Each dot represents a country, and the curved line shows the predicted percentage of births attended by a health worker. Similar to WHO (2006), this analysis found that the coverage rate significantly varied among countries with similar numbers of health workers per 1,000 population, emphasizing the need to incorporate additional variables into the model. The figure also illustrates that countries that covered approximately 90% or more of their births with a health worker had a wide range of health workers per 1,000 population. This is largely because the additional health workers are providing non-birth related care, which makes it difficult to make accurate predictions for these countries without additional data. The vertical line indicates the WHO threshold of 2.28 health workers per 1,000 population (WHO, 2006). Of the 23 countries below this threshold, 14 (or 61%) did not achieve an 80 percent coverage rate for births, which was less than the 85 percent rate found by WHO (2006).

Figure 1: Percentage of Births Attended by a Health Worker Versus Number of Health Workers per 1,000 Population, by Country (n=53)

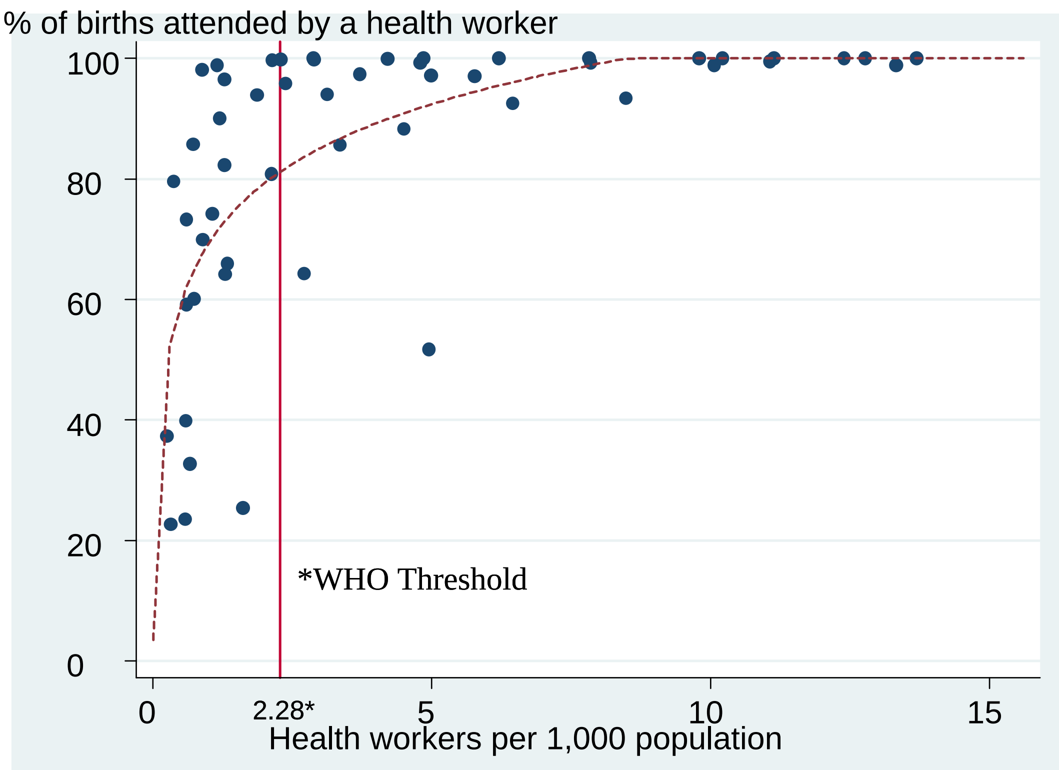
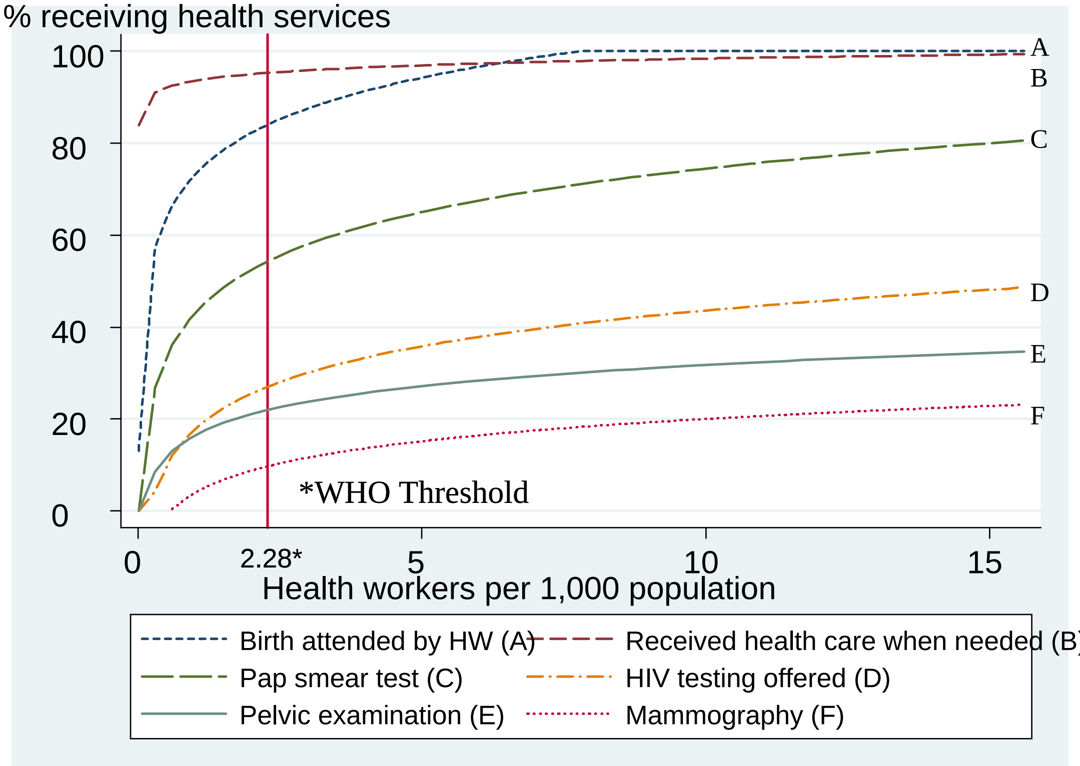


Figure 2 shows the predicted percentage of people in the 18 Sub-Saharan African countries that would receive health care services based on different numbers of health workers per 1,000 population in a country. The figure is based on the multivariate regression results shown in Tables A1 and A2, which includes all 53 countries. The health care services listed in Figure 2 had a statistically significant relationship with the number of health workers, after accounting for each country's population distributions (i.e., land area per capita and percentage of the population living in an urban area). The predictions were based on the Sub-Saharan Africa average land area per capita (0.08 square kilometers) and percentage of the population living in urban areas (38 percent). Based on these results, a country would require different numbers of health workers to achieve particular levels of health care service utilization. For example, to achieve 80 percent coverage of births by a health worker, a country would require 1.7 health workers per 1,000 population (Line A). However, this number of health workers would achieve significantly lower percentages on the other measures such as Pap smear tests (Line C), HIV testing offered during pregnancy (Line D), pelvic examinations (Line E), and mammographies (Line F). If health worker productivity increased, then each of these lines would shift vertically upward (see Box 1 for discussion).

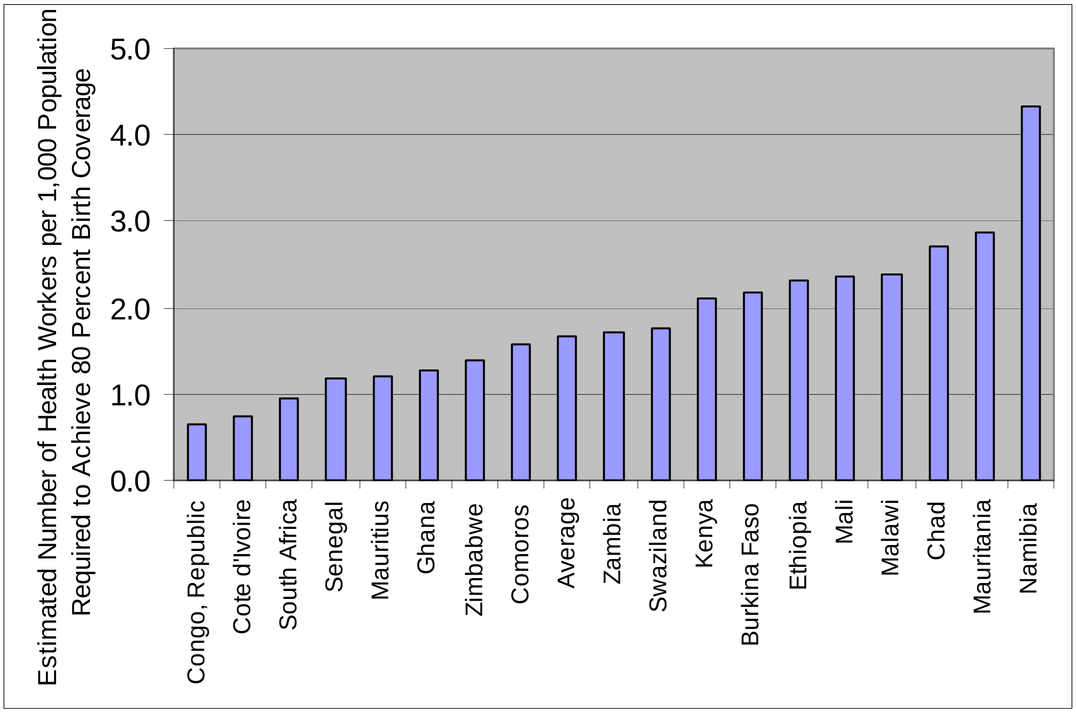
Figure 2: Predicted Percentage of Population Receiving Health Services Based on Number of Health Workers per 1,000 Population for Selected Sub-Saharan African Countries



> Box 1: Service Delivery and Health Worker Productivity
>
> WHO selected the 80 percent coverage rate for births partly because it wanted to set a minimum desired coverage level. However, as seen in Figure 2, the predicted coverage levels for HIV testing offered during pregnancy (Line D), pelvic examinations (Line E), and mammographies (Line F), do not remotely approach a similar standard, even when the number of health workers is significantly increased beyond the WHO's 2.28 health worker threshhold. This means that other factors, such as supplies and equipment, are likely to be the key constraint. Moreover, these tests and examinations are not useful, unless treatments are available.
>
> If investments were made to address these constraints, health worker productivity may increase. In Figure 2, this would cause each of the lines to shift vertically upward, enabling countries to come closer to achieving higher utilization for these health care services, without having to increase the number of health workers.

To illustrate how the required number of health workers may vary based on a country's population distribution, Figure 3 shows the estimated number of health workers per 1,000 population required to achieve 80 percent coverage of births for the 18 Sub-Saharan African countries. The figure is based on the multivariate regression results shown in Tables A1 and A2. The average required number is 1.7 health workers per 1,000 population; the range is from 0.7 in Republic of Congo to 4.3 in Namibia. The required number varies by country because of differing percentages of the population that live in urban areas, and variations in land areas per capita. These factors partially explain why countries with approximately the same number of health workers per 1,000 population had different shares of births that were covered by a health worker (see Figure 1). The average percentage of people living in urban areas among all 18 Sub-Saharan African countries is 38 percent, with a range of 10 percent to 92 percent in Malawi and Republic of Congo, respectively. Based on the analysis, the share of births attended by a health worker is predicted to increase by 0.25 percentage points for every percentage-point increase in the population that lives in an urban area.

Figure 3: Estimated Number of Health Workers per 1,000 Population Required to Achieve 80 Percent Coverage of Births for 18 Selected Sub-Saharan African Countries



The variation among countries in the estimated number of required health workers in Figure 3 shows that the average required number of 1.7 health workers per 1,000 population is a poor estimate for many individual countries (see Box 2 for discussion of Chad). In the same vein, WHO's 2.28 health workers per 1,000 estimate is a poor estimate for many individual countries. The above estimates can be improved by including additional variables that affect the relationship between the number of health workers and health services measures, such as each country's health care system, financing mechanisms, worker training, and geographical characteristics, as well as differences among other health care factors, such as medical facilities, equipment, supplies and pharmaceuticals.[3] In addition to a cross-country needs-based analysis, this analysis could be done within individual countries, using regions or districts.

Box 2: Population Distribution and HRH Requirements for Chad

Chad is a Central African country, and as compared to the 18 Sub-Saharan African countries in the 2002 WHS survey, Chad is less urbanized and has more land area per capita. Specifically, 22 percent of its people reside in an urban area, lower than the 38 percent average for the 18 countries. Chad's square kilometers per capita is 0.14, higher than the 0.07 overall average. Low urbanization is associated with it being more difficult for a Chadian health worker to attend a birth, and the country's coverage rate of births by a health worker was only 23 percent.

As of 2004 (the year of the data in WHO, 2006), Chad had 9.45 million people. It had 2,844 health workers (0.32 per 1,000 population), comprised of 345 doctors (0.04 per 1,000 population) and 2,499 nurses and midwives (0.28 per 1,000 population). The 18 Sub-Saharan African countries, on average, require 1.7 health workers per 1,000 population to achieve 80 percent coverage for births, which would mean that Chad requires 16,000 health workers. This results in an estimated shortage of approximately 13,000 health workers (1.4 per 1,000 population).

However, once Chad's urban and land area factors are included in the model, its HRH requirements are revealed to be 25,500 health workers (2.7 per 1,000 population), resulting in a shortage of approximately 22,500 health workers (2.4 per 1,000 population).

Limitations of and Potential Improvements for Needs-Based Analyses

The required number of health workers per 1,000 population is sensitive to the chosen health measure and varies across countries, based on their population characteristics. The needs-based approach has important limitations, but some can be overcome with additional data. First, the government and private sector have to decide how best to spend their limited health care funds. When the needs-based approach finds that there is a shortage of health workers in a particular country, that finding does not necessarily mean that additional funding should be spent to train and hire additional health workers. It may be more cost effective for funds to be spent on increasing the productivity of existing health workers, either through training and incentives, or by increasing spending on other factors, such as medical facilities, equipment, supplies, or pharmaceuticals. In fact, in order to scale up the health workforce, a country will need to scale up the other components of the health care system. For example, among the 18 Sub-Saharan African countries, the average rate of HIV testing offered during pregnancy was only 19 percent. The binding constraint that limits countries from achieving a higher testing rate may not be health workers, but other factors, such as testing kits and antiretroviral medications for treatment.

Second, the needs-based approach estimates the required number of health workers per 1,000 population, but does not inform decision makers about the optimal distribution of health workers within a country. Therefore, when data are available, the needs-based approach should use data from multiple communities within a country to estimate the required number of health workers at the community level.

Third, the lack of data on factors associated with health care service utilization (e.g., health facilities, equipment, supplies, and pharmaceuticals) and health outcomes (e.g., genetic factors, demographic characteristics, the environment, behavioral choices, education level, and the above-mentioned health systems factors) limits researchers' ability to provide more refined estimates of the number of required health workers. Most health workers do multiple tasks, so it would be ideal to measure productivity for particular tasks. When these data are incorporated, more refined health worker requirement estimates can be made.

Finally, the needs-based approach ignores economic factors such as worker wages and a country's economic ability to train and employ health workers. Taking these factors into account leads to a demand-based approach that determines the number of health workers that a country can actually afford to train and hire (Scheffler et al., 2008; Scheffler 2008).

Appendix: Supplemental Information on Data, Methods, and Results

This appendix includes supplemental information on the data, methods, and results.

<u>Data</u>

The primary data are from the World Health Survey (WHS) 2002, which randomly sampled adults in 70 countries; approximately 4,000 adults per country were asked questions about their household. When a WHS 2002 survey question had more than two possible responses, the analysis collapsed the responses into two responses so multiple measures could more easily be plotted on the same figure. For example, the question that asked a woman when the last time she had a pelvic examination, the possible responses were as follows: less than three years, four to five years, more than five years, and never. These responses were collapsed to indicate whether the woman had a pelvic examination in the last three years.

The analysis includes the following 53 countries by region:[4]

- African Region (18): Burkina Faso, Chad, Comoros, Congo (Republic of), Côte d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mali, Mauritania, Mauritius, Namibia, Senegal, South Africa, Swaziland, Zambia, and Zimbabwe;

- East Mediterranean Region (4): Morocco, Pakistan, Tunisia, and United Arab Emirates;

- European Region (14): Bosnia and Herzegovina, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Latvia, Russian Federation, Slovakia, Slovenia, Spain, Turkey, and Ukraine;

- Region of the Americas (7) Brazil, Dominican Republic, Ecuador, Guatemala, Mexico, Paraguay, and Uruguay;

- South-East Asia Region (5): Bangladesh, India, Myanmar, Nepal, and Sri Lanka;
- Western Pacific Region (5): China, Lao People's Democratic Republic, Malaysia, Philippines, and Viet Nam.

The WHS 2002 includes limitations that stem from issues related to a household survey. The first limitation is whether the sample is nationally representative because of non-response, particularly within sub-populations such as pregnant women. Second, there may be biases introduced when the adult respondent does not have full information about a member in the household that is included within the survey, such as children.

Methods

The analysis estimated two regression models for each of the 12 health care services (numbered 1-12 in Table A1) and health outcomes (numbered 13-14 in Table A1). The dependent variable in each model was the proportion of respondents in a country that received the health care services or achieved the health outcome.[5] The first model included the logarithm of the number of health workers (doctors, nurses, and midwives) per 1,000 population as the only independent variable.[6] The second model included additional variables to control for the percentage of the country's population living in an urban area and the country's land area per capita, because these characteristics may be related to an individual's access to health care services. In order to capture other factors that are specific to Sub-Saharan Africa, the second model also included a dummy variable indicating whether the country was located in Sub-Saharan Africa. In both models, the logarithm transformation of health workers was done because it allows for a non-linear relationship between the number of health workers and the dependent variable, which may be the case because of diminishing marginal returns of an additional health worker. A quadratic specification was also tested for the multivariate models, which on average produced a similar R-squared statistic.

<u>Results</u>

Table A1 presents the bivariate and multivariate regression results for the logarithm of the health worker variable for the 14 sets of models. The results for Models 2 and 3 are for the logarithm of doctors and the logarithm of nurses and midwives, respectively. The bivariate and multivariate regression results had similar statistical significances, but the bivariate parameter estimate magnitudes tended to be larger. The parameter estimates for the health worker variable were statistically significant at the 0.05 level for the following eight dependent variables (Models 1, 4, 5, 6, 7, 8): birth attended by a health worker (either a doctor, nurse, or midwife), birth attended by a doctor, birth attended by a nurse or midwife, a pelvic examination in the last three years, a Pap smear test in the last three years, a mammography in the last three years, HIV testing offered during pregnancy, and health care being received when needed. The models involving children receiving vaccinations did not have a statistically significant relationship with the number of health workers, but whether a child received a vitamin A capsule or similar supplement actually had a negative relationship with the number of health workers per 1,000 population, which requires further investigation. For the health outcome variables in the multivariate models, neither health rating nor health satisfaction were statistically associated with the number of health workers per 1,000 population.

Table A1: Health Care Service Utilization and Health Outcome Measures Regression Results for Health Workers

Dependent Variable	Bivariate Models: log (health workers per 1,000 population)[f]			Multivariate Models: log (health workers per 1,000 population)[f]		
	B	SE	t	B	SE	t
1. Birth attended by health worker (1 yes, 0 no) [a]	0.329	0.05	6.54***	0.301	0.074	4.06***
2. Birth attended by doctor (1 yes, 0 no) [a]	0.390	0.05	7.85***	0.519	0.109	4.76***
3. Birth attended by nurse or midwife (1 yes, 0 no) [a]	0.244	0.07	3.31**	0.206	0.094	2.19*
4. Pelvic examination <3 years (1 yes, 0 no) [b]	0.433	0.06	7.72***	0.153	0.066	2.33*
5. Pap smear test <3 years (1 yes, 0 no) [b]	0.390	0.06	6.66***	0.314	0.086	3.65***
6. Mammography <3 years (1 yes, 0 no) [c]	0.268	0.03	7.84***	0.161	0.048	3.33**
7. HIV testing offered when pregnant (1 yes, 0 no) [d]	0.297	0.06	4.83***	0.258	0.089	2.91**
8. Received healthcare when needed it (1 yes, 0 no)	0.049	0.01	5.39***	0.048	0.014	3.40**
9. Received any vaccination (1 yes, 0 no) [e]	-0.004	0.06	0.07	0.016	0.090	0.18
10. Received DPT vaccination (1 yes, 0 no) [e]	-0.030	0.03	1.19	-0.004	0.039	0.11
11. Received measles vaccination (1 yes, 0 no) [e]	-0.055	0.04	1.31	0.000	0.064	0.00
12. Received vitamin A capsule or similar supplement (1 yes, 0 no) [e]	-0.395	0.05	7.79***	-0.365	0.075	4.89***
13. Health rating (1 very good or good, 0 otherwise)	-0.108	0.04	2.87**	-0.096	0.058	1.64
14. Health satisfaction (1 very satisfied or satisfied, 0 otherwise)	0.000	0.04	0.00	-0.027	0.063	0.43

Abbreviations: B: parameter estimate; SE: standard error; t: t-statistic; *p < 0.05; **p < 0.01; ***p < 0.001
DPT: diphtheria, pertussis (whooping cough) and tetanus
[a] Asked of women who were pregnant in the last 5 years (since January 1998)
[b] Asked of women aged 18-69
[c] Asked of women aged 40-69
[d] Asked of women who were pregnant in the last 2 years (since January 2001)
[e] Asked of children under 5 years old
[f] All statistics are for logarithm of health worker variable, except Model 2 is logarithm of doctor variable and Model 3 is logarithm of a nurse or midwife variable. Other control variables include land (square km) per capita, percent urban, and an African region dummy variable. Number of observations ranged from 48 to 53.

The magnitudes of the parameter estimates have the following interpretation. A one-percent increase in the number of health workers (*hw*) results in a $\beta/100$ unit change in the dependent variable (*y*). For example using Model 1's bivariate result, if the number of health workers increased by 10 percent, then the probability that a birth would be attended by a health worker would be predicted to increase by 0.0329, or 3.29 percentage points [$\Delta y = (\beta / 100) \times \%\Delta hw$; 0.0329 = (0.329/100) $\times$ 10].

Table A2 shows the detailed regression results for the 14 multivariate models. The independent variables and statistics not shown in Table A1 are discussed. The proportion of the population residing in an urban setting was positively associated with pelvic examination in the last three years, Pap smear test in the last three years, and mammography in the last three years (all $p < 0.05$), and approached being positively associated with HIV testing offered during pregnancy and having a birth be attended by a health worker (both $p < 0.06$). A country's land area per capita was not statistically associated ($p < 0.05$) with any of the dependent variables, but it approached being positively associated with having a birth be attended by a nurse or midwife and with whether a child received a vitamin A capsule or similar supplement (both $p < 0.08$). The Sub-Saharan Africa binary variable was not statistically associated with any of the dependent variables, except it had a positive association for having a birth be attended by a doctor ($p < 0.05$). Both of these results require further investigation. The R-squared statistics for the health care services utilization models were 0.41 on average, with a range from 0.07 to 0.73. The R-squared statistics for the health outcome models were lower. The models that included vaccines and health outcomes did not have a statistically significant *F*-statistic ($p < 0.05$), emphasizing the need for additional variables.

Table A2: Health Care Service Utilization and Health Outcome Measures Multivariate Regression Results

Variable	1. Birth attended by health worker	2. Birth attended by doctor	3. Birth attended by nurse or midwife	4. Pelvic examination <3 years	5. Pap smear test <3 years	6. Mammography <3 years	7. HIV testing offered when pregnant
Health workers (log)	0.301*** (0.074)	0.519*** (0.109)	0.206* (0.094)	0.153* (0.066)	0.314*** (0.086)	0.161** (0.048)	0.258** (0.089)
Land (sq km) per capita	-0.352 (0.315)	-0.410 (0.413)	-0.843 (0.455)	-0.072 (0.279)	0.250 (0.366)	0.005 (0.205)	0.192 (0.376)
Urban (% of total population)	0.003 (0.001)	0.001 (0.002)	0.003 (0.002)	0.006*** (0.001)	0.003* (0.001)	0.003** (0.001)	0.003 (0.002)
Sub-Saharan Africa	0.106 (0.063)	0.258* (0.118)	0.134 (0.085)	-0.098 (0.056)	0.053 (0.074)	-0.027 (0.041)	0.081 (0.076)
Constant	0.558*** (0.065)	0.683*** (0.103)	0.563*** (0.094)	0.026 (0.057)	0.239** (0.075)	-0.034 (0.042)	-0.036 (0.077)
N	51	51	51	51	51	51	51
R-squared	0.52	0.61	0.26	0.73	0.53	0.62	0.43
F-statistic	12.6***	17.8***	4.1**	31.6***	12.8***	19.2***	8.6***

Note: results are parameter estimates and standard errors in parentheses. *p <0.05, **p <0.01, ***p <0.001

Variable	8. Received health care when needed it	9. Received any vaccination	10. Received DPT vaccination	11. Received measles vaccination	12. Received vitamin A capsule or similar supplement	13. Health rating	14. Health satisfaction
Health workers (log)	0.048** (0.014)	0.016 (0.090)	-0.004 (0.039)	0.000 (0.064)	-0.365*** (0.075)	-0.096 (0.058)	-0.027 (0.063)
Land (sq km) per capita	-0.008 (0.060)	-0.471 (0.377)	-0.172 (0.162)	-0.185 (0.265)	0.595 (0.313)	0.127 (0.249)	0.048 (0.263)
Urban (% of total population)	0.000 (0.000)	0.001 (0.002)	0.000 (0.001)	0.000 (0.001)	-0.001 (0.001)	-0.001 (0.001)	0.000 (0.001)
Sub-Saharan Africa	-0.006 (0.012)	0.122 (0.076)	0.028 (0.033)	0.083 (0.053)	-0.006 (0.063)	-0.010 (0.050)	-0.036 (0.053)
Constant	0.945*** (0.012)	0.626*** (0.077)	0.934*** (0.033)	0.759*** (0.054)	0.621*** (0.064)	0.664*** (0.051)	0.623*** (0.054)
N	51	49	49	49	49	52	48
R-squared	0.36	0.07	0.07	0.08	0.59	0.15	0.01
F-statistic	6.6***	0.9	0.9	1.0	16.0***	2.0	0.1

Note: results are parameter estimates and standard errors in parentheses. *p <0.05, **p <0.01, ***p <0.001

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Endnotes

[1] The data year for the health workforce supply estimates varied by country; for the 53 countries of interest, most of the years were between 2000 and 2004.

[2] The relationship between the number of health workers per 1,000 population and whether a child received a vitamin A capsule or similar supplement was negative, a finding that requires further investigation. For the health outcome variables, neither health rating nor health satisfaction was statistically associated with the number of health workers per 1,000 population, which is partly attributable to other factors that affect health, such as individual behaviors and the environment.

[3] Theory should determine the variables, along with their specifications, to include in the predictive model. When theory is not conclusive, different models can be tested empirically. One commonly used empirical goal is to minimize the mean of the squared error terms. A cross-validation method could be employed where the model is estimated for a subset of the sample, and predictions are made on the remaining sample. This procedure is repeated, for example, 10 times by excluding a different 10 percent of the sample each time (see Hastie et al., 2001).

[4] The WHS 2002 survey included 70 countries, but all modules of the WHS 2002 were not fielded for 17 countries.

[5] As done in WHO (2006), the analysis also estimated HRH requirements using a dependent variable that was transformed with the arcsine function ($\sin^{-1}$) because proportions violate the variance homogeneity assumption across observations. Because the results were very similar to the models with an untransformed dependent variable, the analysis presents the untransformed models because the parameter estimates are easier to interpret.

[6] When the dependent variable was whether the birth was attended by a doctor, then the key independent variable was the logarithm of the number of doctors per 1,000 population. The analogous change was made when the dependent variable was whether the birth was attended by a nurse or midwife.