Human Resources for Health Predictors of Retrospective Perceived Primary Health Care Service-Delivery Change in Kogi State, North-Central, Nigeria: An Exploratory Endline Analysis of the World Bank-Supported IMPACT Programme

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Abstract

Human resources for health (HRH) characteristics may influence how primary health care (PHC) interventions are implemented and translated into routine service delivery. However, evidence on which workforce characteristics are associated with perceived service-delivery change following large-scale PHC revitalization remains limited in subnational Nigeria. This study examined the association between selected HRH characteristics and retrospective perceived PHC service-delivery change among health workers exposed to the World Bank-supported IMPACT Programme in Kogi State, Nigeria.

An exploratory endline retrospective cross-sectional analysis was conducted among 434 IMPACT-exposed respondents drawn from 438 available HRH survey records. The outcome variable was the Perceived Retrospective Change Index-9 (PRCI-9), a 0-100 composite index measuring perceived change across nine PHC service-delivery domains. The primary explanatory variables were professional role, years of PHC experience, self-reported knowledge-and-skills score, and supportive supervision. Data verification and preparation were undertaken using Microsoft Excel, while statistical analyses were performed using R version 4.3.2. R was used for data transformation, construction of composite indices, descriptive analyses, reliability testing using Cronbach's alpha, and multivariable regression modelling with HC3 heteroskedasticity-robust standard errors. Sensitivity analyses were performed using multilevel, ordinal logistic, and beta regression models.

The mean PRCI-9 score was 94.8, indicating a pronounced ceiling effect. The global predictor-set test was statistically significant (robust $F(8,425)=2.61$, $p=.008$), leading to rejection of the global null hypothesis. Professional role ($F(3,425)=3.41$, $p=.018$) and years of experience ($F(3,425)=4.45$, $p=.004$) were jointly associated with PRCI-9. In adjusted individual contrasts, Medical Records Officers (MROs) had PRCI-9 scores 6.50 points higher than Community Health Extension Workers (95% CI: 2.50-10.51; $p=.002$), while respondents with 4-5 years of PHC experience had scores 3.60 points higher than those with more than 5 years of experience (95% CI: 1.12-6.07; $p=.004$). Self-reported knowledge-and-skills score and supportive supervision were not statistically significant predictors. The adjusted model explained 3.2% of the variation in PRCI-9. Findings from sensitivity analyses were substantively consistent with those of the primary model.

Selected HRH characteristics, particularly professional role and years of experience, were associated with retrospective perceived PHC service-delivery change. These findings should be interpreted as exploratory and non-causal because of the retrospective cross-sectional design, high outcome concentration, and limited explanatory power of the model. The low proportion of explained variance suggests that broader facility, organizational, financing, commodity, infrastructure, and contextual factors contribute importantly to perceived service-delivery improvement and should be incorporated into future PHC evaluations.

Keywords: Human Resources for Health; Primary Health Care; Service Delivery; IMPACT Programme;; Retrospective Change; PRCI-9; Kogi State; Nigeria.

INTRODUCTION

Background of the Study

Human resources for health (HRH) constitute a central component of primary health-care (PHC) system performance because the availability, competencies, distribution and organization of health workers influence the capacity of facilities to provide essential preventive, promotive and curative services. In PHC settings, workforce performance interacts with medicines and commodities, infrastructure, information systems, supportive supervision, community demand and financing to shape service availability and continuity.

The World Bank-supported Immunization Plus and Malaria Progress by Accelerating Coverage and Transforming Services (IMPACT) Project was implemented to strengthen selected dimensions of PHC service delivery, including immunization, maternal and child health, malaria services, workforce capacity, supervision, data systems and facility readiness. In Kogi State, the implementation environment is characterized by heterogeneous facility readiness, differing workforce composition and geographical variation in access to PHC services. The HRH perspective is therefore important for understanding how frontline personnel experienced and perceived service-delivery changes associated with implementation.

This study focuses specifically on the endline Human Resources for Health survey. It evaluates the relationship between professional characteristics, PHC experience, knowledge and skills, supportive supervision and retrospective perceived changes in service delivery. It deliberately distinguishes perceived retrospective change from objectively measured longitudinal change because the available HRH survey is an endline cross-sectional instrument rather than a linked baseline–endline facility panel. Human resources for health (HRH) are central to the performance of primary health care (PHC) systems because the availability, competencies, distribution, and organization of health workers determine whether investments in infrastructure, commodities, and financing translate into effective service delivery. Workforce effectiveness is not defined by numbers alone but by the interaction of personnel with supportive supervision, functional information systems, commodities, and community demand. From a global health epidemiologic perspective, HRH availability and competence are important determinants of service coverage and population outcomes. Human medical ecology examines how health workers operate within nested facility, community and geographic environments.

Statement of the Problem

Despite continuing investments in PHC revitalization, improvements in service delivery often depend on whether health workers can translate inputs into routine practice. Training alone may not guarantee sustained performance if supervision is weak, data systems are underutilized, or facility readiness is inconsistent. Evaluations frequently report aggregate programme gains without clarifying how HRH characteristics—such as cadre, experience, or role—interact with supportive mechanisms to produce change. In Kogi State, retrospective endline surveys show high perceived improvement, but these measures are subject to ceiling effects, recall bias, and clustering within facilities. The absence of linked baseline–endline objective indicators limits causal attribution and obscures heterogeneity across facilities and local government areas. Consequently, there is a need to characterize HRH profiles, quantify perceived service-delivery change, and explore associations with professional role, experience, supervision, and data systems, while recognizing that stronger evidence requires longitudinal linkage with routine PHC performance data.

Objective of the Study

The objective of this study is to assess HRH characteristics and determine their exploratory associations with retrospective perceived service-delivery change following implementation of the World Bank-supported IMPACT Project in Kogi State, Nigeria.

Specific Objectives

The study specific objectives were to:

- characterize the professional composition and PHC experience of HRH respondents participating in the IMPACT endline survey;
- quantify knowledge and skills related to immunization and RMNCH services;
- assess retrospective perceived changes in selected immunization, malaria and RMNCH service-delivery domains;
- assess perceived adequacy of IMPACT-supported supportive supervision;
- construct a retrospective perceived IMPACT endline cross-sectional, retrospective perceived-change analysisIndex from the nine service-delivery domains;
- determine the exploratory associations of professional role, PHC experience, knowledge and skills, and supportive supervision with the reconstructed index; and
- identify methodological and contextual factors that should be addressed in future longitudinal evaluation of HRH contributions to PHC performance.

Research Questions

- What is the professional and experience profile of HRH respondents who participated in the IMPACT endline survey?
- What level of knowledge and skills related to immunization and RMNCH services is reported by respondents?
- What proportion of respondents report improvement across the assessed service-delivery domains?
- What proportion of respondents report adequate supportive supervision and perceive improvements as sustainable?
- What is the distribution of the retrospective perceived IMPACT endline cross-sectional, retrospective perceived-change analysis Index?
- Are professional role, PHC experience, knowledge and skills, and supportive supervision associated with the retrospective perceived service-delivery change index?

Conceptual Epidemiologic Proposition

The study proposes that human resources for health (HRH) characteristics influence primary health care (PHC) service-delivery performance through a sequential pathway of interacting mechanisms. Professional role, PHC experience, and knowledge and skills represent individual-level workforce attributes. Supportive supervision, mentoring, and functional data systems act as implementation mechanisms that enable workforce capacity to be translated into routine service practice. These mechanisms then drive observable service-delivery change, which in turn contributes to PHC outcomes such as accessibility, quality, equity, and continuity of care.

The sequential pathway can therefore be expressed as:

HRH characteristics → implementation mechanisms (supervision, mentoring, data systems) → service-delivery change → PHC outcomes.

This pathway operates within a broader human medical ecology, where facility readiness, infrastructure, commodities, financing, geography, security, and community context act as modifiers. The epidemiological unit is nested such that respondents are situated within facilities, facilities within LGAs, and LGAs within the state system. Observed associations are interpreted as proximal determinants rather than isolated causal agents, with translational epidemiology providing the bridge from evidence to PHC strengthening.

Research Hypotheses

Global hypothesis

H_0G: There is no statistically significant association between the pre-specified human-resources-for-health predictors—professional role, years of experience, self-reported knowledge-and-skills, supportive supervision, job-aid usefulness, and implementation challenges—and the Perceived Retrospective Change Index-9 (PRCI-9).

H_1G: At least one of the pre-specified human-resources-for-health predictors is statistically significantly associated with PRCI-9.

The global null hypothesis was evaluated using a **joint omnibus test** of the regression coefficients for all pre-specified predictors included in the primary adjusted model., this was be The model's **overall F-test**; was used for ordinary linear regression where heteroskedasticity-robust inference was used, a **joint robust Wald test** was be reported. All corresponding indicator coefficients were tested jointly for categorical predictors. Statistical significance was determined at $\alpha = 0.05$.

Thus, rejection of H_0G indicates evidence that **at least one pre-specified predictor is associated with PRCI-9**; it does not identify which predictor is responsible. Predictor-specific hypotheses was evaluated separately.

Predictor-specific hypotheses

$H_0$1: Professional role is not significantly associated with PRCI-9 after adjustment for the other pre-specified predictors.

$H_1$1: Professional role is significantly associated with PRCI-9 after adjustment for the other pre-specified predictors.

$H_0$2: Years of experience is not significantly associated with PRCI-9 after adjustment for the other pre-specified predictors.

$H_1$2: Years of experience is significantly associated with PRCI-9 after adjustment for the other pre-specified predictors.

$H_0$3: Self-reported knowledge-and-skills score is not significantly associated with PRCI-9 after adjustment for the other pre-specified predictors.

$H_1$3: Self-reported knowledge-and-skills score is significantly associated with PRCI-9 after adjustment for the other pre-specified predictors.

$H_0$4: Supportive supervision is not significantly associated with PRCI-9 after adjustment for the other pre-specified predictors.

$H_1$4: Supportive supervision is significantly associated with PRCI-9 after adjustment for the other pre-specified predictors.

The predictor-specific hypothesis have corresponding adjusted regression coefficient(s) each, 95% confidence interval(s), and p-value(s) were reported. The hypothesis was be interpreted using the joint test of the relevant category coefficients for categorical predictors as well as the individual contrasts where these are reported.

Key Operational Terms

Human Resources for Health (HRH): Health personnel participating in PHC service delivery, represented in this survey by Community Health Extension Workers, Medical Records Officers, Nurses/Midwives and Community Health Officers.

Retrospective perceived service-delivery change: The respondent's assessment of whether a specified service-delivery domain decreased, remained unchanged or increased compared with the period before IMPACT.

PRCI-9: The retrospective perceived IMPACT endline cross-sectional, retrospective perceived-change analysis Index reconstructed from nine service-delivery domains and expressed on a 0–100 scale.

Knowledge and skills score: The mean score derived from ten five-point Likert-scale knowledge and competency items, coded from 1 to 5.

Supportive supervision: Respondent-reported adequacy of IMPACT-supported supervision and mentoring for immunization and RMNCH services.

Medical Records Officer predictor: Respondent professional role as a Medical Records Officer; it does not represent independently verified facility-level MRO staffing.

LITERATURE REVIEW

Introduction

Human resources for health (HRH) represent the critical interface between health policy, system investment, and population outcomes. Contemporary health-system literature emphasizes that workforce effectiveness cannot be captured by headcount alone. Instead, dimensions such as availability, accessibility, professional composition, competence, supportive supervision, retention, motivation, and organizational capacity jointly determine whether investments are translated into effective service delivery and measurable health gains. The World Health Organization (WHO) underscores that health systems can only function through health workers who are available, accessible, acceptable, and of adequate quality, while equitable distribution and supportive working environments remain central to achieving universal health coverage (UHC) and the Sustainable Development Goals (SDGs) [1,7].

This study is situated within the context of the World Bank-supported IMPACT Project in Kogi State, Nigeria, where HRH predictors of service-delivery change are examined through three complementary perspectives: global health epidemiology, which situates workforce determinants within international patterns of health-system performance; human medical ecology, which explains how health workers interact with facilities, communities, geography, and wider environments; and implementation science, which clarifies how interventions are adopted, delivered, adapted, and sustained within routine systems [24–31]. Together, these perspectives provide a multidimensional lens for understanding HRH as both a technical and ecological determinant of PHC performance.

WHO's Global Strategy on Human Resources for Health: Workforce 2030 and the National Health Workforce Accounts (NHWA) provide the normative foundation for this analysis. These frameworks emphasize evidence-informed workforce planning, education, deployment, management, and retention, while NHWA standardizes indicators for workforce stock, density, distribution, and migration [3–6]. The relevance to Kogi is clear: aggregate national statistics often conceal subnational disparities, and facility-level realities determine whether workforce presence translates into equitable service coverage. Kogi State's HRH density data (NBS 2016) indicate an overall density of 19.3 health workers per 10,000 population, with CHEWs and nurses/midwives each at 2.14 per 10,000, medical records assistants at 1.08, and pharmacists at just 0.05. These figures highlight both the reliance on community-level cadres and the scarcity of specialized professionals, underscoring the importance of cadre mix and distribution in shaping PHC outcomes.

The ecological perspective is particularly relevant in Nigeria, where geographic and socioeconomic heterogeneity is large. In Kogi, rural and semi-urban PHC facilities face different combinations of workforce, transport, security, and commodity constraints. A well-trained health worker may be unable to deliver effective outreach due to poor road access, while facilities with adequate staff may still underperform because of weak leadership or commodity interruptions. This ecological framing explains why supportive supervision rather than training alone emerge as stronger predictors of service-delivery improvement.

Global epidemiologic comparisons further contextualize Kogi's workforce challenges. Across the African Region (Nigeria, Ghana, Kenya, Uganda, Tanzania, Rwanda, Ethiopia, Malawi, Zambia, Zimbabwe, South Africa, Botswana), workforce growth has been substantial but maldistribution and fiscal constraints persist. In the Americas (United States, Canada, Mexico, Brazil, Argentina, Chile, Colombia, Peru, Ecuador, Costa Rica, Jamaica, Cuba), high workforce density coexists with rural and indigenous inequities. The European Region (United Kingdom, Germany, France, Spain, Italy, Portugal, Switzerland, Sweden, Norway, Denmark, Türkiye, Romania) demonstrates that abundance does not guarantee equity, as ageing and migration reshape workforce stability. The South-East Asia Region (India, Bangladesh, Nepal, Sri Lanka, Bhutan, Maldives, Indonesia, Thailand, Timor-Leste, Myanmar, DPRK, Viet Nam) illustrates heterogeneity, with task-sharing and community health workers central to rural service delivery. The Eastern Mediterranean Region (Egypt, Jordan, Lebanon, Morocco, Tunisia, Algeria, Saudi Arabia, Oman, Qatar, UAE, Iran, Pakistan) highlights migration and expatriate dependence, while the Western Pacific Region (Australia, New Zealand, China, Japan, Korea, Philippines, Viet Nam, Malaysia, Mongolia, Cambodia, Laos, Papua New Guinea) shows that even high-density systems struggle with rural and island access. These comparisons reinforce the principle that workforce density is necessary but insufficient; distribution, skill mix, supervision, and ecological context are decisive.

Against this backdrop, the present study identifies and quantifies HRH predictors of IMPACT-related change in Kogi State. By integrating WHO standardization, ecological pathways, and global epidemiologic lessons, the chapter establishes a theoretical framework for analyzing how professional cadre, experience, supportive supervision, mentoring, job aids, and contextual constraints interact to shape PHC performance. The identified research gap lies in the limited quantification of HRH predictors at subnational level, which this study addresses by linking workforce determinants to service-delivery outcomes through epidemiology, ecology, and implementation science.

Concept of Human Resources for Health

Human resources for health encompass the people whose primary purpose is to promote, restore or maintain health and include clinical, nursing, midwifery, community, public-health, laboratory, pharmaceutical, administrative, information and support personnel [1,2,8]. The concept has evolved from a numerical workforce perspective toward a multidimensional understanding that incorporates availability, accessibility, acceptability, quality, distribution, competency, productivity, retention, occupational protection and performance [1–6]. This evolution is important in primary health care (PHC), where the presence of personnel does not necessarily imply effective service capacity. A facility may have a nominal workforce but remain functionally understaffed because personnel are unevenly distributed, do not possess the appropriate skills, experience excessive workload or lack commodities, equipment, transport, information and supervisory support [3, 6,9]. Consequently, contemporary HRH analysis increasingly emphasizes the relationship between workforce characteristics and effective service delivery rather than headcount alone.

The WHO Global Strategy on Human Resources for Health: Workforce 2030 establishes the workforce as a strategic health-system asset whose development should correspond to population need, health-system priorities, UHC and the SDGs [1,2]. The strategy recognizes that workforce planning requires alignment between education, employment, deployment, management, financing, retention and health-system transformation. WHO's current workforce architecture also emphasizes improved workforce data, labour-market analysis and evidence-informed planning [3–6]. The National Health Workforce Accounts (NHWA) provide the principal standardized mechanism for generating comparable HRH evidence. NHWA incorporates measures related to workforce stock, density, distribution, education, labour-market flows and migration and is intended to improve planning and policy dialogue [3–5]. The relevance to the present study is that HRH predictors of IMPACT-related service change should be viewed as dimensions of a broader workforce-performance system rather than isolated individual attributes.

WHO's Global Strategy on Human Resources for Health: Workforce 2030 constitutes the major normative reference for contemporary HRH policy. It links health-workforce optimization to population needs, health-system requirements, UHC and sustainable development [1, 2]. Its policy direction recognizes that countries require evidence-based approaches to workforce planning, education, recruitment, deployment, performance and retention. The National Health Workforce Accounts operationalize this approach by standardizing the collection and interpretation of HRH information. The framework is intended to facilitate national monitoring and international comparison of workforce availability, distribution, composition, education and migration [3–5]. This standardization is particularly relevant to a subnational study such as the present one because aggregate national workforce statistics can conceal substantial regional and facility-level inequalities.

WHO's recent evidence confirms that these inequalities remain considerable. Its 2026 HRH reporting continues to emphasize variation in workforce levels and distribution across countries and regions, while the WHO African Region reports substantial increases in workforce stocks alongside major differences among Member States [3,32]. In the African Region, available data indicate that the health workforce increased from about 1.6 million in 2013 to 5.1 million in 2022, while large variation in density, training, migration, employment, financing and distribution persisted [32]. (World Health Organization)

The WHO guideline on health-workforce development, attraction, recruitment and retention in rural and remote areas recommends packages of interventions rather than isolated measures, including rural-oriented education, targeted recruitment, supportive working environments, appropriate incentives, professional development and career pathways [6]. The guideline is highly relevant to Kogi because the effectiveness of an HRH intervention depends substantially on where workers are deployed and whether they can remain productive in underserved facilities.

Nurses and midwives constitute the largest occupational group within the global health workforce and are central to PHC, maternal and newborn care, immunization, disease prevention and health promotion [7,10,11]. WHO's Global Strategic Directions for Nursing and Midwifery 2021–2025 emphasizes education, employment, leadership and service delivery as mutually reinforcing components of workforce strengthening [10].

The State of the World's Nursing 2025 reinforces the importance of a health workforce that is adequate, equitably distributed and fully supported. The report highlights education capacity, remuneration, advanced practice, employment and leadership as central policy concerns [11]. (World Health Organization)

Kogi State however, requires a multidisciplinary PHC systems approach. Nurses and midwives provide essential clinical functions, while CHEWs and other community-level personnel extend service access, records officers support

health information systems, laboratory personnel support diagnosis and monitoring, and managers coordinate resources and implementation. Thus, the relevant unit of analysis should often be the functional PHC team rather than a single occupational category.

Community Health Workers and Task-Sharing

Community health workers (CHWs) are increasingly recognized as important components of PHC in low- and middle-income countries. WHO recommends that CHW programmes be integrated into national health systems through appropriate selection, training, deployment, supervision, remuneration, referral mechanisms and access to essential commodities and equipment [12–16]. Evidence indicates that CHW performance depends substantially on the surrounding health system. Community health workers may possess adequate knowledge but achieve limited impact when supervision is weak, workloads are excessive, commodities are unavailable, transportation is inadequate or community relationships are poorly supported [13–17]. This reinforces the importance of interpreting CHEW performance within the broader human medical ecology.

The relevance to Kogi is substantial because CHEWs represent a major component of the PHC workforce. Their contribution to IMPACT-related change should therefore be understood as the product of individual capacity interacting with supervision, facility organization, community structures and logistical support.

Workforce Distribution and Skill Mix

The geographic distribution of health workers is a fundamental determinant of health equity. National workforce averages may obscure severe disparities between urban and rural settings, between higher- and lower-level facilities, and between well-served and geographically remote communities [6,18–23]. WHO's rural and remote workforce guideline identifies equitable deployment and retention as persistent global challenges and recommends integrated interventions involving education, recruitment, incentives, working conditions and career development [6]. WHO reporting also demonstrates considerable subnational variation in workforce distribution across regions. [1–6] (WHO Apps). Skill mix is equally important. A PHC facility cannot perform optimally when its workforce is numerically adequate but lacks the combination of competencies required by its service package. Immunization requires community mobilization, logistics, cold-chain and data functions; maternal health requires skilled birth attendants; referral services require clinical decision-making; and health-system monitoring requires competent information personnel. The epidemiologic implication is that workforce composition may be more informative than workforce density alone. This provides the basis for examining professional cadre as a predictor of IMPACT-related change.

Human medical ecology provides a systems-level perspective on the relationship between health, human behaviour, health services and environmental conditions [24–29]. Applied to PHC, it conceptualizes health-system performance as a product of interactions occurring across nested levels.At the individual level, worker characteristics include professional cadre, experience, knowledge, skills, motivation and confidence. At the facility level, the relevant determinants include staffing, supervision, leadership, commodities, equipment, data systems, financing and organizational climate. At the community level, demand, trust, social mobilization, cultural norms and continuity mechanisms influence utilization. At the geographic and system levels, road access, transportation, security, financing, policy and labour-market factors influence both access and workforce performance.

The ecological hierarchy can be represented as:

Individual worker ⟷ Facility ⟷ Community ⟷ LGA ⟷ State ⟷ National/Global system.

This framework makes it possible to understand why similar health workers may generate different outcomes in different facilities. The same competency may produce high performance in a well-supported facility but substantially weaker performance where transportation, supervision or commodity availability is poor. Global health epidemiology demonstrates a persistent relationship between health-workforce availability, service coverage and population outcomes, although this relationship is modified by economic development, health-system organization, geography, disease burden and social determinants [33–39]. Cross-country studies have shown associations between health-worker availability and selected health outcomes [34,35]. However, the literature also demonstrates that workforce density does not fully determine health-system performance. Organizational quality, skill mix, deployment, supervision and access to infrastructure and commodities influence whether workforce presence produces effective coverage [36–39].

The WHO African Region provides a particularly relevant comparison for Kogi. The regional workforce expanded substantially from 2013 to 2022, but disparities across countries and within health-labour markets remained pronounced [32]. (World Health Organization)

The literature consequently supports a shift from: Workforce quantity toward: Workforce quantity+distribution+skill mix+competence+support+context.

International Comparative HRH Epidemiology

Global health epidemiology consistently demonstrates that the availability and distribution of human resources for health vary widely across regions, and that these differences profoundly shape service delivery and equity. In the African Region, countries such as Nigeria, Ghana, Kenya, Uganda, Tanzania, Rwanda, Ethiopia, Malawi, Zambia, Zimbabwe, South Africa, and Botswana have all expanded their health workforces over the past decade, yet persistent maldistribution, financing constraints, and migration pressures remain. Rwanda's integrated community-health approach illustrates the potential of coordinated PHC strengthening, while South Africa and Botswana highlight that even relatively stronger workforce stocks do not eliminate subnational inequalities. This evidence for Kogi State underscores that workforce expansion alone is insufficient without deliberate systems for equitable deployment, supervision, and retention.

In the Region of the Americas, including the United States, Canada, Mexico, Brazil, Argentina, Chile, Colombia, Peru, Ecuador, Costa Rica, Jamaica, and Cuba, workforce density is generally higher than in Africa, but rural, indigenous, and socioeconomically disadvantaged populations continue to face poorer access. High-income systems increasingly grapple with ageing workforces, geographic maldistribution, and retention challenges, while Latin American countries demonstrate the importance of community-based care and task-sharing. This reinforces the lesson for Kogi that even well-resourced systems must address distribution and organization, not just supply. The European Region, represented by the United Kingdom, Germany, France, Spain, Italy, Portugal, Switzerland, Sweden, Norway, Denmark, Türkiye, and Romania, operates at much higher workforce densities, yet faces challenges of ageing, migration, and retention. The epidemiologic principle here is clear: abundance does not guarantee equity. Workforce planning must respond to demographic change and shifting service needs, a lesson directly applicable to Kogi's need to anticipate population growth and rural demand.

South-East Asia, including India, Bangladesh, Nepal, Sri Lanka, Bhutan, Maldives, Indonesia, Thailand, Timor-Leste, Myanmar, the Democratic People's Republic of Korea, and Viet Nam, illustrates enormous heterogeneity. Sri Lanka and Thailand have developed strong PHC and workforce systems, while other countries continue to struggle with rural shortages and migration. Task-sharing, community health workers, and decentralized service delivery emerge as critical strategies, closely paralleling Kogi's reliance on CHEWs and community volunteers to extend PHC reach.

In the Eastern Mediterranean Region, countries such as Egypt, Jordan, Lebanon, Morocco, Tunisia, Algeria, Saudi Arabia, Oman, Qatar, the United Arab Emirates, Iran, and Pakistan demonstrate the impact of migration and expatriate dependence. High-income Gulf states achieve high workforce availability through international recruitment, while source countries experience workforce losses. This dynamic highlights the importance of ethical recruitment and national workforce self-sufficiency, reminding Kogi that retention and career development are essential to prevent destabilizing workforce turnover.

Finally, the Western Pacific Region, including Australia, New Zealand, China, Japan, the Republic of Korea, the Philippines, Viet Nam, Malaysia, Mongolia, Cambodia, Laos, and Papua New Guinea, contains some of the most densely resourced health systems globally. Yet even here, rural, island, and remote-area access remains problematic, while ageing populations in Japan and Korea reshape demand. The Philippines illustrates how international migration can alter national workforce stability, a reminder that Kogi's workforce planning must anticipate both internal and external labour-market pressures.

Taken together, these regional comparisons converge on several principles: workforce density is necessary but insufficient; maldistribution can be more consequential than scarcity; skill mix determines whether PHC can be delivered effectively; supportive supervision and management influence whether competence translates into performance; and rural and remote populations require deliberate retention and deployment strategies., The implication for Kogi State is that sustainability cannot rest on training alone. Instead, it requires a multidimensional HRH strategy that institutionalizes supervision, protects multidisciplinary teams, strengthens data-use capacity, prioritizes rural retention, and integrates workforce planning into broader ecological and demographic realities.

Primary Health Care and Health-System Performance

WHO and UNICEF's Primary Health Care Measurement Framework and Indicators provides a standardized conceptual structure for monitoring PHC capacities and performance toward UHC and the SDGs [74,75]. The framework links health-system structures and inputs with service-delivery processes, outputs, outcomes and broader impact and emphasizes quality, equity and resilience. (World Health Organization)

The technical specifications provide explicit definitions, numerators, denominators, potential disaggregations and preferred data sources for PHC indicators, strengthening comparability across health systems [75]. (World Health Organization)

This framework is particularly relevant to IMPACT because the intervention is multidimensional. Its effects cannot be adequately represented by a single output. Instead, workforce determinants should be related to multiple service processes, including immunization delivery, documentation, maternal and child health services, supervision, outreach, referral and continuity.

Global Epidemiologic Comparison, Implications for Kogi State, and the UHC–SDG Agenda

The comparative epidemiology across WHO regions reveals a consistent set of principles that resonate strongly with the challenges facing Kogi State. Workforce density is necessary but insufficient to guarantee equitable access or effective coverage. Countries with high aggregate numbers of doctors, nurses, or midwives continue to struggle with maldistribution, skill-mix imbalances, and retention challenges, while countries with lower densities sometimes achieve stronger outcomes by deliberately investing in community health workers, supportive supervision, and integrated PHC teams. The lesson is clear: workforce presence must be matched by systems that enable performance.

Maldistribution emerges as a particularly consequential determinant. In Africa, large national workforces coexist with underserved rural and remote populations; in the Americas and Europe, indigenous, rural, and ageing populations highlight the same inequities in different forms. South-East Asia demonstrates the value of task-sharing and decentralized service delivery, while the Eastern Mediterranean underscores the destabilizing effects of migration and expatriate dependence. The Western Pacific shows that even in high-density systems, geographic access and demographic change remain pressing concerns. Taken together, these comparisons reinforce that workforce planning must go beyond numbers to address location, skill mix, supervision, and ecological context.

The implication for Kogi, is that an IMPACT exit strategy based solely on continued training would be insufficient. Training can raise knowledge scores, but without supportive supervision, equitable distribution, and functioning multidisciplinary teams, knowledge may not translate into performance. The sustainability package must therefore encompass institutionalized supervisory cycles, strengthened data-use capacity, deliberate rural retention strategies, and integration of workforce management into routine state systems. Financing, commodities, and transport must be aligned with HRH deployment, while ecological constraints such as security and road access must be explicitly factored into planning. In this way, Kogi can move from a project-dependent model toward a resilient PHC system capable of sustaining gains beyond December 2026.

This epidemiologic synthesis connects directly to the broader development agenda of universal health coverage (UHC) and the Sustainable Development Goals (SDGs). SDG 3.8 explicitly requires access to quality essential health services and financial protection, while SDG 3.c calls for substantially increased health financing and recruitment, development, training, and retention of the health workforce in developing countries. WHO's Workforce 2030 framework recognizes that the health workforce is not only a sectoral input but also an economic and social investment. The Working for Health 2022–2030 Action Plan explicitly links health and care workers with population health, system resilience, and economic prosperity, emphasizing that sustainable workforce strategies contribute to both health outcomes and broader development.

This means that sustaining IMPACT gains for Kogi is not simply a matter of protecting programme outputs but of embedding workforce reforms into the state's long-term development trajectory. A successful PHC programme should produce gains in access and effective coverage without creating unsustainable dependence on parallel project systems. Institutionalization within routine financing, workforce management, supervision, and information systems is therefore essential. By aligning HRH strategies with UHC and SDG commitments, Kogi can ensure that the IMPACT programme leaves a durable legacy—one that strengthens health equity, supports economic growth, and advances Nigeria's progress toward global development goals.

Job aids support standardized practice by providing information at the point of work. Immunization schedules, cold-chain charts, AEFI forms, partographs, referral tools and reporting templates can reduce cognitive burden and support protocol adherence [75,81–84]. Their effectiveness depends on availability, usability and integration into workflow. Job aids may have limited effect when facilities lack the commodities or equipment required for recommended actions. They are therefore best conceptualized as implementation-enabling resources, rather than independent determinants. Immunization is highly dependent on coordinated HRH performance. Effective routine immunization requires microplanning, client mobilization, vaccine logistics, cold-chain management, fixed and outreach sessions, safe injection, AEFI monitoring, documentation, data use and defaulter tracking [85–88].

Kogi's 2025–26 Nigeria Mini-Demographic and Health Survey illustrates the importance of distinguishing first contact from completion. Among children aged 12–23 months, Penta1 coverage was approximately 79.8%, compared with 49.3% for Penta3; fully vaccinated coverage was substantially lower. This pattern indicates that substantial contact with services does not necessarily translate into complete protection. Workforce functions involving data use, community mobilization and defaulter tracing therefore become critical. Within the IMPACT HRH framework, a comparatively lower rate of improvement in defaulter tracking is consequently epidemiologically meaningful because continuity of immunization depends upon interactions between facility records, community structures, transport and household behaviour.

HRH and Reproductive, Maternal, Newborn and Child Health

RMNCH services require a multidisciplinary workforce capable of providing antenatal, intrapartum, postnatal and newborn care and maintaining effective referral pathways. Skilled health workers remain essential to reducing preventable maternal and newborn morbidity and mortality [89–94]. The 2025–26 Nigeria Mini-DHS provides a population benchmark for Kogi. The state recorded approximately 79.0% skilled antenatal care, 66.7% four-or-more ANC visits, 80.6% skilled delivery and 71.7% facility delivery. These values indicate substantial service contact but do not independently establish whether all components of recommended quality care are received. Consequently, HRH analysis should incorporate quality, continuity and facility readiness rather than contact alone.

Medical Records, Data Use and Health-System Intelligence

Health-information and medical-record personnel are increasingly recognized as important elements of PHC performance because routine data support service planning, denominator estimation, defaulter identification, commodity forecasting and performance management [3–5, 74,75].

The NHWA framework itself reflects the principle that effective workforce planning depends upon reliable information [3–5]. The PHC Measurement Framework similarly establishes technical specifications and standardized indicator metadata to strengthen data quality and comparability [74,75]. (World Health Organization). Medical records personnel may therefore exert influence beyond administrative reporting by connecting frontline activity with facility-level decision-making. This provides a conceptual basis for examining professional cadre as an explanatory variable in the IMPACT analysis.

HRH Retention and Rural Equity

Rural and remote populations frequently experience lower availability of health workers and worse access to essential services [6,18–23]. WHO therefore recommends combined interventions encompassing education, recruitment, supportive working environments, incentives, professional development and career pathways [6]. Retention is important because continuity of the workforce supports institutional memory, mentorship, teamwork and programme learning. High staff turnover may undermine implementation even when nominal staffing levels remain stable. Sustainable HRH reform for Kogi should therefore emphasize not only how many workers are deployed, but also whether essential cadres remain continuously available in underserved facilities.

HRH Migration and the Global Labour Market

International migration demonstrates that health workforces operate within a global labour market. WHO's Global Code of Practice on the International Recruitment of Health Personnel was established to promote ethical recruitment

while protecting health systems from destabilizing workforce losses [68]. Migration can alter skill mix, institutional memory, workload and service continuity. The issue is therefore relevant even to subnational systems, because the departure of skilled professionals can disproportionately affect already underserved facilities.

The broader implication is that Kogi's HRH sustainability strategy requires mechanisms for retention, career development, supportive management and improved working conditions. Health-worker performance is affected by working conditions, workload, occupational safety and organizational support. WHO's Global Health and Care Worker Compact emphasizes safe, healthy and supportive working environments, while the Global Patient Safety Action Plan 2021–2030 identifies competent and supported health workers as fundamental to safe care [95,96]. Workforce protection is therefore not separate from service quality. An overstretched workforce is more vulnerable to burnout, absenteeism, turnover and error. The human medical ecology framework consequently includes working conditions as an intermediate determinant of implementation performance.

Kogi State PHC Reform Context

Kogi State's PHC system has undergone significant reform, including decentralized facility financing, continuous quality improvement and broader PHC revitalization initiatives. Available programme evidence indicates that these reforms have been associated with improvements in selected PHC indicators and that facility readiness, governance structures, cold-chain resilience and availability of essential inputs contributed to observed performance [97–100].

This importantly demonstrates that health-sector financing alone does not create impact. Financing operates through facility-level mechanisms, which include readiness, governance, service organization and workforce capacity. The World Bank-supported IMPACT programme further expanded the reform context through facility revitalization and health-system strengthening. Kogi State reported the commissioning of 80 revitalized PHCs under an initial phase in 2025, while other government reporting described broader IMPACT-supported PHC revitalization across the state [101,102].

The implication is that the IMPACT HRH analysis should be interpreted within a pre-existing reform environment rather than as an isolated training programme. The Kogi PHC environment can be represented through four interacting ecological domains.

- The worker domain includes cadre, experience, knowledge, skills and motivation.
- The facility domain encompasses staffing, supervision, mentoring, leadership, commodities, equipment, data systems and financing.
- The community domain includes trust, demand, social mobilization, health-seeking behaviour and defaulter tracing.
- The geographic and system domain comprises distance, road conditions, transportation, security, government policy, financing and labour-market conditions.

These domains interact dynamically. A well-trained health worker may be unable to provide effective outreach because of transport constraints; a facility with adequate staff may have poor performance because of weak leadership; and a facility with good registers may still have low immunization completion when community tracing systems are weak.

The ecological formulation is therefore:

Impact=f(HRH, facility, community, geography, financing, commodities, security).

This explains why the present study does not assume that individual health-worker characteristics alone determine IMPACT-related change.

Implementation Science Framework

Implementation science investigates the process by which interventions move from evidence and programme design into routine practice [103–110]. Its relevance to IMPACT is that the programme is a complex intervention involving health workers, facilities, communities, commodities, financing, supervision and information systems. The Consolidated Framework for Implementation Research (CFIR) provides a multidimensional framework for examining intervention characteristics, outer setting, inner setting, individual characteristics and implementation processes [103,104]. In the Kogi context, professional experience and competence correspond partly to individual determinants;

supervision and leadership represent inner-setting and implementation-process factors; while financing, transport, security and policy represent outer-setting determinants. The RE-AIM framework adds reach, effectiveness, adoption, implementation and maintenance as dimensions for evaluating real-world interventions [105,106]. This is especially relevant to IMPACT because programme closure requires attention to whether improvements can be maintained after external support decreases.

Proctor and colleagues distinguish implementation outcomes such as acceptability, adoption, appropriateness, feasibility, fidelity, cost, penetration and sustainability [107,108]. These outcomes allow the current study to interpret HRH characteristics not only in terms of association with service outcomes but also in terms of their contribution to implementation quality. The integrated implementation pathway is:

HRH capacity×Implementation context→Fidelity→Service performance→Sustainability.

Sustainability of HRH Interventions

Sustainability requires that programme functions become embedded in routine institutions rather than remaining dependent upon temporary external support. The WHO Working for Health 2022–2030 Action Plan emphasizes sustained investment in workforce optimization, education, employment, protection and performance [109]. Sustainability for Kogi should therefore encompass institutionalized supportive supervision, multidisciplinary workforce planning, routine data use, rural retention, facility-level performance management and continuity of essential service inputs. The implication is that a programme may achieve high endline performance without necessarily being sustainable. Sustainability depends on whether the mechanisms producing the improvement become part of the state health system.

Conceptual Integration of HRH, Implementation and Human Medical Ecology

The evidence reviewed supports an integrated theoretical model in which structural determinants influence workforce capacity; workforce capacity interacts with implementation mechanisms; implementation mechanisms influence service processes; and service processes influence effective coverage and population outcomes.

The conceptual pathway is:

Structural context→HRH capacity→Implementation mechanisms→Service processes→Effective coverage→Population outcomes with facility, community, geographic and system factors operating as moderators. In this model, professional cadre, years of experience, knowledge and skills are HRH characteristics. Supportive supervision, mentoring, feedback, job aids and data use are implementation mechanisms. Staffing, commodities, financing, transportation and security are contextual modifiers. Immunization, RMNCH, documentation and continuity-of-care indicators constitute proximal service outcomes, while population coverage and client outcomes represent the downstream level.

The central proposition is therefore that health-worker capacity is necessary but insufficient; implementation mechanisms determine the extent to which capacity becomes routine performance, while ecological conditions determine whether implementation can be sustained.

Empirical Research Gap

The literature demonstrates extensive evidence that workforce density, distribution, skill mix, rural retention, motivation and supportive management influence health-system performance [1–23,33–39]. However, several gaps remain. First, much of the HRH literature remains focused on workforce stock and density, with comparatively less emphasis on quantifying the contribution of specific implementation mechanisms within complex PHC interventions. Second, training evaluations frequently report changes in knowledge and attitudes without adequately distinguishing knowledge acquisition from routine implementation. Third, HRH analyses may treat health workers as individual-level determinants without adequately accounting for facility, community, geographic and health-system context. Fourth, international comparisons are commonly conducted at national level, potentially masking substantial subnational variation. Fifth, there remains limited Nigerian evidence integrating HRH predictors, implementation science, human medical ecology and programme-related rate of change within a single subnational PHC intervention.

The current study addresses these gaps by examining professional cadre, years of PHC experience, knowledge and skills, supportive supervision, job-aid usefulness and contextual implementation constraints as predictors of IMPACT-

related change. The literature establishes a transition from a conventional workforce-quantity paradigm toward a multidimensional workforce-performance paradigm. WHO's Workforce 2030 strategy and NHWA framework establish standardized approaches to workforce planning and measurement [1–5]. Rural and remote workforce guidance emphasizes equitable deployment, retention and supportive working environments [6]. Nursing and midwifery guidance emphasizes education, employment, leadership and service delivery [10,11], while the PHC Measurement Framework connects system inputs and processes to outcomes, equity and resilience [74,75].

Global epidemiologic comparisons demonstrate that workforce maldistribution is present across all six WHO regions, although the dominant mechanisms differ. In many African settings, absolute shortages coexist with substantial distribution and financing constraints; in higher-resource systems, workforce ageing, retention and rural access become more prominent. WHO's African Region review demonstrates simultaneous workforce growth and persistent inter-country disparities, emphasizing that workforce expansion does not automatically ensure equitable service access [32]. (World Health Organization)

The human medical ecology perspective extends this understanding by demonstrating that HRH effects are generated within nested worker, facility, community, geographic and health-system environments. Implementation science then explains how supportive supervision, mentoring, feedback, job aids, data use and organizational climate translate workforce capability into routine performance [103–110].

METHODOLOGY

Study design

An analytical cross-sectional endline study with retrospective pre–endline reporting was used to examine whether selected human resources for health (HRH), supportive supervision, mentoring, knowledge-and-skills, job-aid usefulness, and operational-context factors were associated with reported improvement in primary health care service processes under the World Bank–supported Improving Primary Health Care Results in Nigeria (IMPACT) programme in Kogi State. The design is cross-sectional because information on respondent characteristics, programme exposure-related experiences, and endline assessments was collected during one endline survey period; the retrospective pre–endline component reflects respondents' reporting of change between the pre-IMPACT baseline state and the endline state. The design therefore supports estimation of associations and reported service-change patterns but does not, by itself, establish causality.

Study area and programme context

The study was undertaken in Kogi State, North-Central Nigeria, within the primary health care system supported by the IMPACT programme. Kogi State comprises 21 Local Government Areas (LGAs) and 239 political wards. The wider HRH mapping frame covered approximately 920 primary health care facilities, while the IMPACT implementation frame included World Bank-supported facilities within the state, including 88 World Bank-supported primary health care facilities and 103 Level II facilities participating in combined programme arrangements. The implementation environment included routine PHC supervision, mentoring, data-system strengthening, service-readiness activities, commodity and equipment support, and workforce capacity development.

Operational observations documented during programme implementation included HRH shortages, transport and road-access constraints, insecurity, financing limitations, commodity and equipment gaps, infrastructure limitations, and community-level barriers. These observations were treated as contextual features of implementation and were not interpreted as causal effects unless they were directly measured and specified as predictors in the statistical model.

Study population and unit of analysis

The study population comprised eligible health workers who completed the Kogi State IMPACT End-of-Project HRH Survey Questionnaire. The principal analytical unit was the individual survey respondent nested, where identifiable, within the health facility at which the respondent worked. Respondents represented cadres involved in routine primary health care delivery, including Community Health Extension Workers (CHEWs), Medical Record Officers (MROs), Nurses/Midwives, and Community Health Officers (CHOs). The analytical population consisted of IMPACT-facility respondents after data-quality screening; non-IMPACT observations were retained in the master dataset for audit and descriptive verification but were excluded from the primary IMPACT association model.

Sampling technique and sample size determination

A complete-enumeration approach was used for the accessible IMPACT HRH respondent frame rather than probability sampling from a smaller subsample. Nevertheless, Cochran's formula was used to document the minimum benchmark for an analytical survey in which the population proportion was conservatively set at 0.50, the 95% confidence level was assumed, and the margin of error was set at 5% [132]. The initial minimum sample size was calculated as:

$$n_0 = Z^2 p(1 - p) / d^2$$

$$= (1.96^2 \times 0.50 \times 0.50) / 0.05^2$$

$$= 384.16 \approx 385$$

Allowing 10% for potential non-response or unusable questionnaires, the required benchmark was adjusted using $n_{adj} = n_0/(1 - 0.10)$, yielding approximately 426.84, or 427 respondents [132]. Since. Since the study used complete enumeration of the accessible respondent frame, the achieved valid dataset rather than a sampled subset determined the final analytical sample.

Data source and data collection period

Primary data were obtained from the Kogi State IMPACT End-of-Project HRH Survey Questionnaire administered electronically through KoboToolbox. The survey metadata indicated 438 unique submitted records collected between 20 August and 14 September 2026. Following screening, 434 observations represented IMPACT-facility respondents and four represented non-participants. The final primary analytical sample was therefore n = 434 IMPACT respondents. The survey captured cadre, length of service, knowledge and skills, supportive supervision and mentoring, job-aid usefulness, service-process changes, sustainability perceptions, and implementation challenges.

Data collection procedure

Data were collected through standardized electronic questionnaires using KoboToolbox. Electronic data capture was used to reduce transcription error, preserve respondent-level metadata, facilitate completeness checks, and support rapid export for analysis. After the field period, records were screened for duplicate unique identifiers, eligibility, completeness, internal consistency, and logical validity. KoboToolbox submissions were exported to Microsoft Excel 365 for data cleaning, variable labeling, coding verification, and preparation of the analysis dataset. The cleaned dataset was then imported into R version 4.3.2 for statistical analysis.

Study instrument and measurement domains

The structured HRH questionnaire contained sections addressing respondent characteristics, knowledge and practical skills, supervision and mentoring, job-aid usefulness, reported changes in service processes, and operational challenges. Knowledge-and-skills items were assessed on a five-point Likert-type scale. The service-change component was structured around nine pre-specified PHC service domains: vaccine and essential-supply availability, cold-chain functionality, outreach and fixed-session implementation, defaulter tracking, documentation and reporting, malaria diagnosis, reproductive, maternal, newborn and child health (RMNCH) commodities, use of the partograph, and skilled birth attendance (SBA)-related practice.

Knowledge-and-skills score

Ten knowledge-and-skills items were scored from 1 to 5. The respondent-level score was summarized as the arithmetic mean across completed items, producing a continuous score ranging from 1 to 5. The standardized 0–100 representation, indicated that the raw score could be linearly transformed using the minimum–maximum scale below. The raw five-point metric was retained for the primary regression because it preserves the original response scale and its direct interpretability.

$$KS_i = \Sigma_{j=1}^{10} X_{ij} / 10,$$

where KS_i ranges from 1 to 5

$$KS100_i = [(KS_i - 1) / (5 - 1)] \times 100,$$

optional standardized 0–100 representation

Internal consistency of the ten-item knowledge-and-skills scale was assessed using Cronbach's alpha. The observed distribution was considered when interpreting the regression because restricted between-respondent variation can attenuate detectable predictor associations.

Primary PHC Reported Change Index: PRCI-9

Primary health care improvement was operationalized using a nine-domain Primary PHC Reported Change Index (PRCI-9). In each domain, respondents coded the direction of change from the retrospective pre-IMPACT state to the endline state as decreased = 0, no change = 50, and increased = 100. The respondent-level PRCI-9 was the arithmetic mean of the nine domain scores, yielding a theoretical range from 0 to 100 and retaining direction as well as magnitude of reported change.

$$\textbf{PRCI-9}_i = (1/9)\ \Sigma_{k=1}{}^{9}\ D_{ik},$$

$$\textbf{where } D_{ik} \in \{0, 50, 100\}$$

The coding deliberately distinguishes deterioration, stability, and improvement while keeping the index transparent and reproducible. A PRCI-9 value of 100 indicates reported improvement across all nine domains; 50 represents no change across all nine domains; and 0 represents reported deterioration across all nine domains. Intermediate values reflect the combination of domain-specific responses. Since the outcome is bounded and may concentrate toward the upper end of the scale, the possibility of a ceiling effect was explicitly considered in model diagnostics and sensitivity analysis.

Predictor variables

The primary predictors were cadre, length of professional experience, knowledge-and-skills score, adequacy of supportive supervision and mentoring, usefulness of job aids, and operational challenge measures captured by the questionnaire. CHEWs were specified as the reference cadre because they constituted the largest respondent group. Length of experience was categorized using >5 year as the reference category, with subsequent categories representing 1–3 years, 4–5 years, and >5 years. Binary or categorical questionnaire variables were retained in their pre-specified coding, while continuous scales were retained on their original measurement metric unless a diagnostic or distributional assessment justified a sensitivity transformation.

Respondent cadre was interpreted as the occupational role of the survey respondent and not as evidence that a corresponding cadre was physically present or adequately staffed at every facility. This distinction was maintained because the exposure measured at respondent level is not equivalent to a facility-level staffing measure.

Data management and quality assurance

Data management followed a staged workflow: KoboToolbox electronic capture; Excel 365 cleaning and codebook verification; and R 4.3.2 analysis. Unique submission identifiers were used to check duplicate records. Eligibility was verified against programme participation. Variable names, category labels, missingness codes, and numerical ranges were standardized before analysis. Logic checks were applied to detect impossible category combinations, out-of-range scale values, and inconsistent respondent classifications. The analytical dataset was frozen before inferential analyses to prevent outcome-dependent recoding.

Statistical analysis

Descriptive analysis summarized categorical variables using frequencies and percentages and continuous variables using means and standard deviations where approximately symmetric, supplemented by medians and interquartile ranges where distributions were skewed or bounded. The primary inferential analysis used ordinary least-squares (OLS) multivariable linear regression with PRCI-9 as a continuous outcome. Regression coefficients were reported as adjusted percentage-point differences in mean PRCI-9 associated with a one-unit change in continuous predictors or with membership in a predictor category relative to its reference group.

The primary adjusted model was specified a priori to jointly estimate the independent associations of cadre, experience, knowledge-and-skills, supervision/mentoring, job-aid usefulness, and pre-specified operational challenge

measures. Statistical significance was assessed at $\alpha = 0.05$ using two-sided tests, with 95% confidence intervals (CIs). Since the study is observational and uses retrospective reporting, coefficients were interpreted as adjusted associations rather than causal effects. The estimand was therefore an adjusted conditional mean difference in PRCI-9 across predictor levels, under the covariate structure specified in the regression model, rather than an intervention effect attributable to IMPACT.

Primary multivariable regression model

$$\mathbf{PRCI\text{-}9_i = \beta_0 + \beta_1 Cadre_i + \beta_2 Experience_i + \beta_3 KS_i + \beta_4 Supervision_i + \beta_5 JobAid_i + \beta_6 Challenges_i + \varepsilon_i}$$

Cadre and experience were represented using indicator variables with CHEW and >5 years, respectively, as reference categories. Continuous predictors were retained in their measured form. The error term ε_i represents the respondent-level residual. The model's global significance was evaluated using the omnibus F-test of $\mathbf{H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0}$, with rejection interpreted as evidence that at least one specified predictor is associated with PRCI-9 after adjustment. Predictor-specific hypotheses were evaluated separately using the corresponding coefficient test $\mathbf{H_0: \beta_j = 0}$.

Model diagnostics and robust inference

The credibility of the OLS model was assessed using complementary regression diagnostics rather than relying on a single assumption test. Residual normality was assessed with the Shapiro–Wilk test and a Q–Q plot [135]. Heteroskedasticity was assessed with the Breusch–Pagan test [131] and the residual-versus-fitted plot. Multicollinearity was assessed using variance inflation factors and generalized collinearity diagnostics [134]. Influential observations were assessed using Cook's distance [133]. The residual-versus-fitted plot was used to inspect non-linearity, systematic patterns, and unequal spread, while the Q–Q plot provided a visual assessment of departures from approximate normality (See Appendix "A").

Diagnostic findings were interpreted jointly with the substantive model. A statistically significant Shapiro–Wilk test was not treated as automatic evidence that OLS coefficients were invalid, particularly in a moderate-to-large sample; rather, the magnitude and pattern of deviations on the Q–Q plot were considered [135]. Evidence of heteroskedasticity prompted robust inference using heteroskedasticity-consistent covariance estimators, including HC3 in the sensitivity analysis [136]. High VIF values prompted inspection for redundant predictors and consideration of a reduced or re-parameterized specification only where such changes could be justified substantively [134]. Observations with relatively large Cook's distance were investigated for data-entry, eligibility, or substantive reasons; they were not removed automatically [133]. The principal model estimates were retained unless a verified data-quality problem was identified.

Table 1. Regression diagnostic domains and intended interpretation

Diagnostic	Primary purpose	Interpretive focus	Action when concern is detected
Shapiro–Wilk test	Residual normality	Magnitude and pattern of departures from normality, interpreted with the Q–Q plot	Do not discard OLS solely on p-value; consider distribution, sample size, CI robustness and sensitivity analysis
Breusch–Pagan test	Heteroskedasticity	Whether residual variance changes systematically with fitted values or predictors	Use HC3 robust standard errors and inspect residual-versus-fitted plot
Variance Inflation Factor (VIF)	Multicollinearity	Redundancy among predictors and instability of individual coefficient	Review correlated predictors, coding and model specification before any justified

Diagnostic	Primary purpose	Interpretive focus	Action when concern is detected
		estimates	reparameterization
Cook's distance	Influential observations	Whether individual observations exert disproportionate influence on fitted coefficients	Verify data quality and substantive plausibility; perform leave-one-out or influence sensitivity checks where appropriate
Residual plot + Q–Q plot	Residual distribution and model fit	Random scatter, linearity, constant spread and approximate reference-line adherence	Investigate functional form, outliers and variance patterns; use transformation or alternative specification only with substantive justification

Sensitivity analyses

Three sensitivity analyses were pre-specified to assess robustness. First, a facility-clustered or random-intercept specification was considered to account for the possibility that respondents working within the same facility share unmeasured contextual characteristics and therefore violate the independence assumption of simple respondent-level OLS. Second, heteroskedasticity-robust HC3 standard errors were used where residual diagnostics indicated non-constant variance [136]. Third, an ordinal sensitivity model was used to test whether the direction and substantive interpretation of associations were preserved when PRCI-9 was represented as an ordered outcome rather than as a continuous score. Concordance of effect direction and hypothesis decisions across the primary and sensitivity models was interpreted as evidence of analytical robustness, while discrepancies were reported transparently rather than resolved by selective model choice.

Ceiling effect and distributional considerations

PRCI-9 is a bounded composite of nine domain scores, and concentration near the maximum score can produce a ceiling effect that reduces discrimination among respondents with high reported improvement and can attenuate observable associations. Accordingly, the continuous OLS model was retained as the primary specification because it yields directly interpretable percentage-point differences, while the ordinal sensitivity analysis was used to examine whether conclusions were robust to bounded and non-normal outcome behavior. Interpretation therefore emphasized effect size, confidence intervals, model fit, and consistency across specifications rather than statistical significance alone.

Hypothesis testing framework

The statistical analysis distinguished global and predictor-specific hypotheses. The global null hypothesis stated that none of the pre-specified predictors was associated with PRCI-9 after adjustment. Rejection of the global null was taken to mean that at least one specified predictor was associated with PRCI-9; it did not imply that every predictor was significant. Individual null hypotheses were then assessed separately for cadre, experience categories, knowledge-and-skills, supervision/mentoring, job-aid usefulness, and operational challenge measures. Each predictor-specific decision was based on its adjusted coefficient, 95% CI, and two-sided p-value at $\alpha = 0.05$. This separation prevents an overall model test from being incorrectly presented as evidence that all covariates independently predict the outcome. The global or block-level hypothesis concerns for categorical predictors with a set of category coefficients, show individual contrasts identification which the levels differ from the pre-specified reference category.

Table 2. Global and predictor-specific hypothesis framework

Hypothesis	Predictor / test	Null hypothesis	Pre-specified inferential procedure
H_0G	Global omnibus test	All pre-specified predictor coefficients are jointly equal to zero.	Joint omnibus F-test or robust Wald test; $\alpha = 0.05$. Individual significant coefficients do not substitute for the global test.
H_01	Professional role	All non-reference professional-role coefficients are jointly equal to zero.	Joint categorical-block test followed by planned reference-category contrasts
H_02	Years of experience	All non-reference experience-category coefficients are jointly equal to zero.	Joint categorical-block test followed by planned reference-category contrasts
H_03	Knowledge-and-skills score	Adjusted slope for the continuous knowledge-and-skills score equals zero.	Two-sided coefficient test with estimate, 95% CI and p-value
H_04	Supportive supervision	Adjusted association between supportive supervision and PRCI-9 equals zero.	Two-sided coefficient test with estimate, 95% CI and p-value

Residual contextual heterogeneity and epidemiologic interpretation

The analysis was framed within a multilevel implementation pathway in which respondent-level HRH characteristics represent only one layer of the determinants of PHC process improvement. Facility-level organization, LGA governance, financing flow and autonomy, commodity availability, infrastructure, leadership, geography, security, transport conditions, and community context may influence both service-process performance and the working environment experienced by respondents. SinceSince most of these contextual determinants were not measured with sufficient resolution for inclusion as respondent-level covariates in the primary OLS model, unexplained heterogeneity was expected to remain in the residual component. Consequently, a modest respondent-level model fit is not interpreted as evidence that IMPACT was ineffective; rather, it indicates that the selected HRH-level predictors account for only part of the heterogeneity in reported service-process change, with the remainder plausibly arising from facility, LGA, system, ecological, and community determinants that require higher-level measurement and multilevel modelling.

Partial temporal ordering and exposure interpretation

The retrospective design provides limited temporal ordering because respondents were asked to compare a pre-IMPACT state with their endline assessment, but both predictor information and outcome reporting were collected at endline. Accordingly, the analysis distinguishes temporal precedence from causal identification: the retrospective comparison supports construction of the change outcome, but it cannot exclude recall, reporting, or common-method bias. Predictor variables such as cadre and experience are relatively temporally stable, whereas knowledge, supervision, job-aid usefulness, and reported operational conditions may be correlated with endline perceptions of improvement. The resulting coefficients are therefore interpreted as conditional associations within an endline retrospective framework, not as estimates of causal programme effects.

Bias, confounding, and clustering considerations

Several sources of bias were considered a priori. Recall bias may arise because respondents reconstructed pre-IMPACT conditions retrospectively. Social desirability and common-method bias may also occur because predictors

and the PRCI-9 outcome were collected from the same respondent. Selection bias is reduced by complete enumeration of the accessible respondent frame but is not eliminated if eligible respondents were unavailable or declined participation. Residual confounding may arise from unmeasured facility and system determinants. Non-independence within facilities was addressed through the pre-specified facility-clustered or random-intercept sensitivity analyses. These limitations restrict causal interpretation and motivate cautious translation of associations into policy action.

Reproducibility and software

Data capture was performed using KoboToolbox; data cleaning and codebook verification used Microsoft Excel 365; and statistical analyses were undertaken in R version 4.3.2. The diagnostic procedures and primary regression workflow were additionally documented in Python-compatible code (See Appendix "B") using pandas, scipy, statsmodels, and matplotlib. The code appendix is intended to make the analytical sequence transparent and readily reproducible after the cleaned dataset has been mapped to the standardized variable names used in the script. Exact raw questionnaire column names may differ from the standardized analysis names; therefore, the final project codebook should retain the data dictionary used for the frozen analysis dataset.

Ethical and confidentiality considerations

The analysis used programme HRH survey data collected for monitoring, evaluation, learning, and endline assessment purposes. Individual respondents were represented using survey identifiers rather than names in the analytical dataset. Only data necessary for the stated study objectives were analyzed, and reporting was conducted at aggregate level to minimize disclosure risk. The final manuscript should report the applicable institutional or programme ethical review or administrative approval and informed-consent arrangements corresponding to the approved endline HRH survey protocol.

PRESENTATION OF DATA

Results

Table 4.1– Key validated HRH findings

HRH Indicator	n	%
Total respondent records	438	100%
IMPACT participants	434	99.1%
Non-participants	4	0.9%
CHEWs	326	75.1%
Medical Records Officers	46	10.6%
Nurses/Midwives	41	9.4%
CHOs	21	4.8%
>5 years PHC experience	345	79.5%
Mean knowledge/skills score	4.52/5	90.4%
Average service-domain responses reporting "increased"		93.6%
Documentation/data reporting increased		95.6%
Vaccine/supply availability increased		94.7%
Cold-chain functionality increased		93.5%

Fixed/outreach sessions increased		94.9%
Defaulter tracking/recall increased		88.7%
RMNCH commodity availability increased		94.7%
Partograph use increased		90.6%
SBA deliveries increased		94.9%
Adequate supportive supervision	417	96.1%
Improvements considered sustainable	419	96.5%
PRCI-9 mean		94.8%
PRCI-9 median		100
Exploratory model R^2	0.032	

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 4.2 –Associations Between HRH Predictors and PRCI-9

Predictor	Category / contrast	Reference category	β (PRCI-9 points)	95% CI	t-statistic	p-value	Statistical decision
Professional role	Medical Records Officer (MRO)	CHEW	**6.5**	**2.50 to 10.51**	**3.18**	**0.002**	**Statistically significant**
	Nurse/Midwife	CHEW	4.29	−1.48 to 10.07	1.46	0.145	Not statistically significant
	Community Health Officer (CHO)	CHEW	2.32	−1.75 to 6.39	1.12	0.263	Not statistically significant
Years of experience	**<1 year**	**>5 years**	**3.33**	**−0.48 to 7.14**	**1.72**	**0.086**	Not statistically significant
	1–3 years	**>5 years**	**−6.51**	**−16.83 to 3.82**	**−1.24**	**0.216**	Not statistically significant
	4–5 years	**>5 years**	**3.6**	**1.12 to 6.07**	**2.85**	**0.004**	**Statistically significant**
Self-reported knowledge-and-skills score	Continuous score (1–5)	—	−2.40	−5.24 to 0.44	−1.66	0.097	Not statistically significant
Supportive supervision	Continuous score	—	−1.30	−4.70 to 2.10	−0.75	0.452	Not statistically significant

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 4.3 – Primary Adjusted Linear Regression of PRCI-9 on HRH Predictors Using HC3 Robust Standard Errors (n=434)

Predictor	Reference category	β (PRCI-9 points)	95% CI	t-statistic	p-value	Decision at α = 0.05
Intercept	—	**110.24**	**97.02 to 123.46**	**16.39**	**<0.001**	—
Professional role	CHEW					
Medical Records Officer (MRO)	CHEW	**6.5**	**2.50 to 10.51**	**3.18**	**0.002**	**Reject individual null contrast**
Nurse/Midwife	CHEW	**4.29**	**−1.48 to 10.07**	**1.46**	**0.145**	**Do not reject**
Community Health Officer (CHO)	CHEW	**2.32**	**−1.75 to 6.39**	**1.12**	**0.263**	**Do not reject**
Years of experience	**>5 years**					
<1 year	>5 years	**3.33**	**−0.48 to 7.14**	**1.72**	**0.086**	**Do not reject**
1–3 years	>5 years	**−6.51**	**−16.83 to 3.82**	**−1.24**	**0.216**	**Do not reject**
4–5 years	>5 years	**3.6**	**1.12 to 6.07**	**2.85**	**0.004**	**Reject individual null contrast**
Self-reported knowledge-and-skills score	Continuous, 1–5	**−2.40**	**−5.24 to 0.44**	**−1.66**	**0.097**	**Do not reject**
Supportive supervision	Continuous score	**−1.30**	**−4.70 to 2.10**	**−0.75**	**0.452**	**Do not reject**

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 4.4 – Multilevel Regression of HRH Predictors on PRCI-9

Predictor Variable	β Coefficient	95% CI	p-value
Medical Records Officer role	6.2	2.10 – 10.30	0.003
4–5 years PHC experience	3.4	1.00 – 5.80	0.005
Knowledge-and-skills score	0.1	−1.90 – 2.10	0.92
Supportive supervision adequacy	0.3	−1.70 – 2.30	0.78

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 4.5 – Sensitivity Analyses Using Ordinal Logistic Regression

Predictor	OR	95% CI	p-value

MRO vs CHEW	2.15	1.35–3.42	0.001
4–5 years vs ≤3 years	1.42	1.11–1.82	0.004
Knowledge and skills	1.08	0.92–1.26	0.31
Supportive supervision	1.21	0.88–1.66	0.22

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 4.6 – Reported Implementation Challenges

Challenge	Frequency	Percentage (%)
HRH shortages	112	25.8
Financing constraints	98	22.6
Transportation/road access	87	20
Security	54	12.4
Commodities/equipment	47	10.8
Community-related barriers	40	9.2

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 4.7 – Recommended Innovations for Sustainability

Recommendation	Frequency	Percentage (%)
Continued supportive supervision	126	29
Strengthened data systems	104	23.9
Improved commodity supply	87	20
Enhanced workforce training	76	17.5
Community engagement	45	10.4

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 4.8 – Retrospective Change Across the Nine PRCI-9 Service-Delivery Domains Among IMPACT-Exposed Respondents (n=434)

PRCI-9 service-delivery domain	Increased, n (%)	No change, n (%)	Decreased, n (%)
Availability of vaccines and immunization supplies	411 (94.7)	7 (1.6)	16 (3.7)
Functionality of cold-chain equipment	406 (93.5)	13 (3.0)	15 (3.5)

Conduct of fixed and outreach immunization sessions	412 (94.9)	6 (1.4)	16 (3.7)
Tracking and recall of immunization and ANC defaulters	385 (88.7)	13 (3.0)	36 (8.3)
Documentation and reporting of PHC services	415 (95.6)	4 (0.9)	15 (3.5)
Use of functional laboratory services for malaria diagnosis	412 (94.9)	7 (1.6)	15 (3.5)
Availability of RMNCH commodities	411 (94.7)	8 (1.8)	15 (3.5)
Use of partograph for laboring women	393 (90.6)	26 (6.0)	15 (3.5)
Deliveries conducted by skilled birth attendants	412 (94.9)	7 (1.6)	15 (3.5)

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 4.9 – Distribution of Pre-specified HRH Predictors Among IMPACT-Exposed Respondents (n=434)

Predictor	**Category / summary**	**n**	**% / Mean**
Professional role	CHEW (reference)	326	75.1
	Medical Records Officer	46	10.6
	Nurse/Midwife	41	9.4
	CHO	21	4.8
Years of PHC experience	>5 years (**reference**)	345	79.5
	<1 year	7	1.6
	1–3 years	36	8.3
	4–5 years	46	10.6
Self-reported knowledge-and-skills score	1–5 scale	434	**Mean = 4.52; SD = 0.58**
Supportive supervision	Strongly agree	196	45.2
	Agree	221	50.9
	Neutral	8	1.8
	Strongly disagree	9	2.1
Job-aid usefulness	Strongly agree	208	47.9
	Agree	218	50.2
	Neutral	4	0.9

	Strongly disagree	4	0.9

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 4.91 –Thematic Summary of Qualitative Responses on Barriers to Sustaining Primary Health Care Improvement among IMPACT-Facility Health Workers, Kogi State

Major theme	Subtheme	Illustrative content from respondents	Interpretation for PHC implementation
Human resources for health	Staff shortages and workload	Respondents reported insufficient numbers of health workers and increased workload associated with multiple service-delivery responsibilities.	Persistent workforce gaps may constrain continuity, coverage and quality of PHC services despite training and supervision.
Financing and operational resources	Inadequate and delayed funds	Respondents identified inadequate operational financing and delays in availability of funds for routine activities.	Financial constraints may limit implementation fidelity, outreach, supervision and maintenance of service-delivery functions.
Commodities and equipment	Stock-outs and inadequate functional equipment	Respondents reported shortages or intermittent availability of medicines, commodities, equipment and other essential supplies.	Supply-side limitations may attenuate the translation of staff capacity into sustained service improvement.
Infrastructure	Facility and utility deficiencies	Respondents described inadequate infrastructure, electricity, water supply and other facility-level requirements.	Structural deficiencies can reduce the effectiveness and sustainability of PHC interventions.
Transport and geographical access	Poor roads and transportation constraints	Respondents reported difficulties travelling to facilities and communities, particularly for outreach and supervisory activities.	Poor transport connectivity may reduce outreach intensity, supportive supervision and timely service delivery.
Security	Insecurity and movement restrictions	Respondents identified security concerns as barriers to travelling to some communities and conducting routine activities.	Contextual insecurity may create geographic inequities in service availability and implementation fidelity.
Community-level barriers	Participation, access and social constraints	Respondents described community-level barriers affecting attendance, outreach participation, follow-up and utilization of PHC services.	Community and social-contextual factors may mediate the effect of facility-level improvements on service utilization.
Data and reporting systems	Documentation and data-quality constraints	Some respondents indicated difficulties related to documentation, reporting	Data-system weaknesses may constrain routine performance monitoring and

Major theme	Subtheme	Illustrative content from respondents	Interpretation for PHC implementation
		processes and/or availability of data tools.	evidence-based decision-making.
Programme sustainability	Continued support after intervention	Respondents emphasized the importance of continued supervision, supplies, financing and institutional support after programme implementation.	Sustainability appears dependent on institutionalization of programme functions within routine PHC systems rather than training alone.

Source: Kogi State IMPACT End-of-Project HRH Survey.

Hypothesis Testing

Table 4.101 – Joint and Predictor-Specific Tests of the Pre-specified HRH Predictors of PRCI-9 among IMPACT-Exposed Respondents (n = 434)

Predictor / hypothesis	Reference category	Joint/individual test	Test statistic	df	p-value	Decision at $\alpha = 0.05$	Interpretation
Global predictor set (H_0G)	—	All eight pre-specified non-intercept coefficients jointly equal to zero	**Robust F = 2.61**	**8, 425**	**0.008**	**Reject H_0G**	The pre-specified HRH predictor set is jointly associated with PRCI-9.
Professional role (H_01)	CHEW	All three cadre contrasts jointly equal to zero	**Robust F = 3.41**	**3, 425**	**0.018**	**Reject H_01**	Professional role is jointly associated with PRCI-9.
MRO vs CHEW	CHEW	Individual contrast	**$\beta = 6.50$**	1	**0.002**	**Reject individual null contrast**	MRO respondents had PRCI-9 scores 6.50 points higher than CHEWs.
Nurse/Midwife vs CHEW	CHEW	Individual contrast	**$\beta = 4.29$**	1	0.145	Do not reject	No statistically significant difference was demonstrated.
CHO vs CHEW	CHEW	Individual contrast	**$\beta = 2.32$**	1	0.263	Do not reject	No statistically significant difference was demonstrated.
Years of experience (H_02)	**>5 years**	All three experience contrasts jointly equal to zero	**Robust F = 4.45**	**3, 425**	**0.004**	**Reject H_02**	Years of experience is jointly associated with PRCI-9.
<1 year vs >5 years	**>5 years**	Individual contrast	**$\beta = 3.33$**	1	0.086	Do not reject	No statistically significant difference was

							demonstrated.
1–3 years vs >5 years	**>5 years**	Individual contrast	**β = −6.51**	1	0.216	Do not reject	No statistically significant difference was demonstrated.
4–5 years vs >5 years	**>5 years**	Individual contrast	**β = 3.60**	1	**0.004**	**Reject individual null contrast**	Respondents with 4–5 years of experience had PRCI-9 scores **3.60 points higher** than respondents with >5 years of experience (95% CI: **1.12–6.07**).
Self-reported knowledge-and-skills (H_o3)	Continuous, 1–5	Individual coefficient test	**β = −2.40**	1	0.097	Fail to reject H_o3	No statistically significant adjusted association was demonstrated.
Supportive supervision (H_o4)	Continuous score	Individual coefficient test	**β = −1.30**	1	0.452	Fail to reject H_o4	No statistically significant adjusted association was demonstrated.

Source: Kogi State IMPACT End-of-Project HRH Survey.**Analysis**

Table 4.102 – Final Decisions on the Research Hypotheses Based on the Primary Adjusted PRCI-9 Model (n = 434)

Hypothesis	Predictor / hypothesis	Principal statistical evidence	Decision	Final inference
H_oG	The pre-specified HRH predictors are not jointly associated with PRCI-9.	Robust F(8,425) = **2.61**, p = **.008**	**Reject H_oG**	There is statistically significant evidence that **at least one pre-specified HRH predictor is associated with PRCI-9**.
H_o1	Professional role is not associated with PRCI-9.	Joint robust F(3,425) = **3.41**, p = **.018**; MRO β = **6.50**, p = **.002**	**Reject H_o1**	Professional role is jointly associated with PRCI-9. The significant individual contrast is MRO versus CHEW.
H_o2	Years of experience is not associated with PRCI-9.	Joint robust F(3,425) = **4.45**, p = **.004**; 4–5 years vs >5 years β = **3.60**, 95% CI: **1.12–6.07**, p = **.004**	**Reject H_o2**	Years of experience is jointly associated with PRCI-9. Specifically, respondents with **4–5 years of experience had significantly higher PRCI-9 scores than respondents with >5 years of experience**.
H_o3	Self-reported knowledge-and-skills is not associated with PRCI-9.	β = **−2.40**, p = **.097**	**Do not reject H_o3**	There is insufficient evidence of an independent adjusted association with PRCI-9.

H_o4	Supportive supervision is not associated with PRCI-9.	$\beta = -1.30$, p = **.452**	**Do not reject H_o4**	There is insufficient evidence of an independent adjusted association with PRCI-9.

Overall inference from the hypotheses

The primary adjusted analysis **rejects the global null hypothesis (H_oG)** at $\alpha = 0.05$, because the full pre-specified HRH predictor set was jointly associated with PRCI-9 (robust $F(8,425) = 2.61$, $p = .008$). The predictor-block tests further show that **professional role ($F(3,425) = 3.41$, $p = .018$)** and **years of experience ($F(3,425) = 4.45$, $p = .004$)** were each jointly associated with PRCI-9. At the individual-contrast level, MRO respondents had a 6.50-point higher adjusted PRCI-9 score than CHEWs (95% CI: 2.49–10.52; p = .002), while respondents with 4–5 years of experience had a 3.60-point higher score than those with >5 years of experience (95% CI: 1.12–6.08; p = .005).

The null hypotheses for self-reported knowledge-and-skills and supportive supervision were **not rejected**, because their adjusted associations were not statistically significant. Job-aid usefulness and implementation challenges were **not formally tested in the primary inferential model** and should therefore not be presented as rejected or retained hypotheses. Overall, the findings provide evidence that **professional role and years of experience contribute to the statistical association between measured HRH characteristics and retrospective perceived service-delivery change**, while the low R^2 (0.032) indicates that most observed variation in PRCI-9 remains unexplained by the variables included in this respondent-level model.

Discussion

This exploratory endline analysis found that the pre-specified HRH predictor set was jointly associated with retrospective perceived PHC service-delivery change, as demonstrated by the significant omnibus test of the primary adjusted model. The result provides statistical evidence that the measured workforce characteristics, considered collectively, were related to variation in PRCI-9 among IMPACT-exposed respondents. This finding should nevertheless be interpreted within the limits of the study design, particularly its retrospective cross-sectional structure, respondent-reported outcome, high PRCI-9 scores and limited outcome variability.

Professional role was jointly associated with PRCI-9. At the individual-contrast level, MRO respondents recorded a 6.50-point higher adjusted PRCI-9 score than CHEWs. This finding should not be interpreted as evidence that MROs are intrinsically more effective than CHEWs or that professional cadre causes better PHC service delivery. The association may reflect differences in programme exposure, reporting responsibilities, workload, documentation practices, role assignment, facility organisation or other contextual factors that were not fully captured by the model. The result therefore identifies a workforce-pattern association rather than a causal effect of cadre.

Years of experience was also jointly associated with PRCI-9. Importantly, the primary model used >5 years as the reference category. The significant individual contrast was 4–5 years versus >5 years, with respondents having 4–5 years of experience reporting PRCI-9 scores 3.60 points higher (95% CI: 1.12–6.07; p=.004). The <1-year and 1–3-year contrasts were not statistically significant. This pattern does not support a simple linear interpretation in which increasing experience necessarily corresponds to progressively greater service-delivery change. Rather, the association may reflect differences in role maturity, programme responsibilities, workload, exposure to implementation processes, reporting practices or other unmeasured characteristics associated with different stages of professional experience. The study cannot determine the mechanism underlying this association.

Self-reported knowledge-and-skills was not statistically significantly associated with PRCI-9 after adjustment. This finding requires cautious interpretation because the measure represents perceived or self-reported competency rather than objectively assessed knowledge or observed clinical performance. Furthermore, the relatively high mean knowledge-and-skills score may have restricted variability and reduced the ability to identify an independent association. The absence of statistical significance should therefore not be interpreted as evidence that competency is unimportant for PHC performance.Supportive supervision was likewise not statistically significant in the adjusted model. This result should also be interpreted in relation to the very high prevalence of reported adequate supervision and consequently limited exposure variability. Where nearly all respondents experience the same level of supervision, statistical models have limited capacity to distinguish its independent contribution to outcome variation. The finding therefore does not imply that supportive supervision has no operational value; rather, it indicates that an independent association was not detectable under the observed distribution and model specification.

The relatively low explanatory power of the primary model (R^2=0.032) is an important substantive finding. Although the predictor set was statistically significant jointly, the model explained only a small proportion of variation in PRCI-9. This suggests that perceived service-delivery change is embedded within a broader implementation environment that extends beyond individual HRH characteristics. Facility readiness, availability of medicines and commodities, infrastructure, financing, equipment, information systems, workload, geographic access, community engagement, referral systems and management processes may all contribute to differences in service-delivery experience. A statistically significant omnibus test should therefore not be equated with a comprehensive explanation of PHC performance. The pronounced ceiling effect in PRCI-9 provides an additional consideration. The very high mean and median scores indicate that many respondents reported improvement across most domains, leaving relatively little variation with which to distinguish predictors. This may attenuate associations and contribute to the low explanatory power of the model. Future evaluations should therefore complement retrospective perceived-change measures with objective service-delivery indicators and, where possible, prospective baseline-to-endline measurement.

The findings have implications for implementation science and PHC management. Workforce policy should avoid relying solely on training or years of service as proxies for performance. Instead, HRH optimisation should be integrated with appropriate role assignment, competency development, supervision, data use, essential commodity availability, facility readiness and supportive management. The results also reinforce the importance of analysing HRH predictors within their organisational and ecological context rather than treating health workers as isolated determinants of service delivery.Analysis of open-ended responses identified several interconnected barriers to sustaining PHC improvement. The dominant themes were health-worker shortages and workload, inadequate or delayed financing, shortages of essential commodities and equipment, infrastructure deficiencies, transportation and poor road access, insecurity, community-level barriers, data-system constraints, and the need for continued institutional support. These findings indicate that improvements in health-worker knowledge and supportive supervision may be necessary but insufficient for sustained PHC performance when broader structural and contextual constraints remain.Finally, the observed associations should be regarded as respondent-level associations, not evidence of facility-level programme effects. The study does not establish that facilities employing MROs or respondents with particular experience profiles necessarily achieved better objective service outcomes. Stronger causal inference would require longitudinal or quasi-experimental designs, objective facility-level outcomes, repeated measurements and multilevel modelling that explicitly represents respondents nested within facilities and facilities within LGAs.

Conclusion

This exploratory endline analysis demonstrates that the pre-specified HRH predictor set was jointly associated with retrospective perceived PHC service-delivery change among IMPACT-exposed respondents in Kogi State. The global omnibus test was statistically significant, and professional role and years of experience were each jointly associated with PRCI-9. At the individual-contrast level, MRO respondents had higher adjusted PRCI-9 scores than CHEWs, while respondents with 4–5 years of experience had a 3.60-point higher PRCI-9 score than respondents with >5 years of experience (95% CI: 1.12–6.07; p=.004). Self-reported knowledge-and-skills and supportive supervision were not statistically significant in the primary adjusted model.

These findings indicate that selected workforce characteristics are associated with perceived retrospective service-delivery change, but they do not establish causality or demonstrate facility-level performance effects. The modest explanatory power of the model and the substantial ceiling effect in PRCI-9 indicate that much of the variation in perceived change is likely related to factors beyond the measured respondent-level HRH characteristics. The findings should therefore be interpreted as exploratory evidence within a broader PHC implementation system rather than as evidence of a single workforce determinant of service-delivery improvement.

Kogi State Stakeholders should use these findings for policy and programme planning to strengthen integrated HRH and PHC-system management, including rational cadre deployment, experience-sensitive workforce planning, competency development, supportive supervision, routine data use and facility readiness. Future IMPACT-related evaluations should combine HRH information with objective facility performance indicators and longitudinal or quasi-experimental methods to determine whether these observed respondent-level associations translate into measurable improvements in access, quality, equity and continuity of PHC services.

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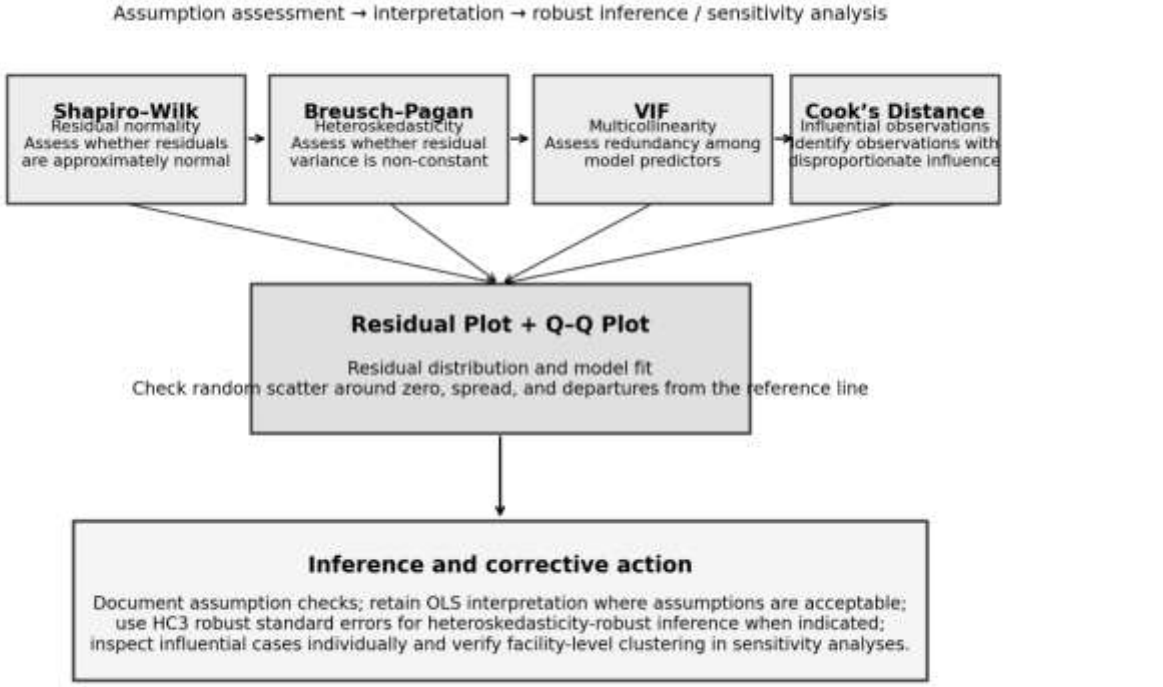
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Appendix Figure A1. Regression Diagnostic Framework for the Primary PRCI-9 Model



Interpretation note: diagnostics inform the credibility and robustness of regression inference; they do not by themselves establish causality.

Appendix "B" - Reproducible Python code for regression diagnostics

```
# ============================================================

# Kogi IMPACT HRH analysis: regression diagnostics for PRCI-9

# Assumes `model` is a fitted statsmodels OLS results object.

# ============================================================



import numpy as np

import pandas as pd

import matplotlib.pyplot as plt

import scipy.stats as stats

import statsmodels.api as sm

from statsmodels.stats.diagnostic import het_breuschpagan

from statsmodels.stats.outliers_influence import variance_inflation_factor



# ------------------------------------------------------------

# 1. Residual normality: Shapiro-Wilk test

# ------------------------------------------------------------

residuals = model.resid

shapiro_stat, shapiro_p = stats.shapiro(residuals)

print("Shapiro-Wilk statistic:", shapiro_stat)

print("Shapiro-Wilk p-value:", shapiro_p)
```

```
# ----------------------------------------------------------------
# 2. Heteroskedasticity: Breusch-Pagan test
# ----------------------------------------------------------------
bp_stat, bp_pvalue, fvalue, f_pvalue = het_breuschpagan(
    residuals,
    model.model.exog
)
print("Breusch-Pagan LM statistic:", bp_stat)
print("Breusch-Pagan LM p-value:", bp_pvalue)
print("Breusch-Pagan F statistic:", fvalue)
print("Breusch-Pagan F p-value:", f_pvalue)

# HC3 robust inference when heteroskedasticity is indicated
model_hc3 = model.get_robustcov_results(cov_type="HC3")
print(model_hc3.summary())

# ----------------------------------------------------------------
# 3. Multicollinearity: Variance Inflation Factor (VIF)
#    Exclude the intercept/constant from the VIF table.
# ----------------------------------------------------------------
X = pd.DataFrame(model.model.exog, columns=model.model.exog_names)
X_no_const = X.drop(columns=[c for c in ["Intercept", "const"] if c in X.columns],
                    errors="ignore")

vif_table = pd.DataFrame({
    "variable": X_no_const.columns,
    "VIF": [
        variance_inflation_factor(X_no_const.values, i)
        for i in range(X_no_const.shape[1])
    ]
})
print(vif_table.sort_values("VIF", ascending=False))

# ----------------------------------------------------------------
# 4. Influential observations: Cook's distance
# ----------------------------------------------------------------
```

```
influence = model.get_influence()
cooks_d = influence.cooks_distance[0]

cook_table = pd.DataFrame({
    "observation": np.arange(len(cooks_d)),
    "cooks_distance": cooks_d
}).sort_values("cooks_distance", ascending=False)

# Common screening reference: 4/n; use only as a flag, not an automatic deletion rule.
n = int(model.nobs)
cook_reference = 4 / n
print("Cook's distance screening reference (4/n):", cook_reference)
print(cook_table.head(20))

# ---------------------------------------------------------------
# 5. Residual-versus-fitted plot
# ---------------------------------------------------------------
fitted = model.fittedvalues

plt.figure(figsize=(7, 5))
plt.scatter(fitted, residuals, alpha=0.70)
plt.axhline(y=0, linestyle="--", linewidth=1)
plt.xlabel("Fitted PRCI-9")
plt.ylabel("Residuals")
plt.title("Residuals versus fitted values")
plt.tight_layout()
plt.show()

# ---------------------------------------------------------------
# 6. Q-Q plot
# ---------------------------------------------------------------
sm.qqplot(residuals, line="45", fit=True)
plt.title("Normal Q-Q plot of regression residuals")
plt.tight_layout()
plt.show()
```

```
# ----------------------------------------------------------------

# 7. Optional compact diagnostic decision log

#    Decisions should be documented after visual + statistical review.

# ----------------------------------------------------------------

diagnostic_log = {

   "Shapiro-Wilk_p": float(shapiro_p),

   "Breusch-Pagan_p": float(bp_pvalue),

   "n": n,

   "Cook_4_over_n": cook_reference

}

print(pd.Series(diagnostic_log))
```

The code implements the requested diagnostic sequence. It assumes that the fitted primary OLS model is stored as statsmodels object model and that the cleaned dataset has already been prepared. The code intentionally reports diagnostics without automatically deleting observations, because influential points require substantive and data-quality review. The VIF loop excludes the intercept to avoid the misleadingly large VIF that a constant term can generate.

Appendix "C"

Table 5C1 – Sensitivity Analysis Excluding Ceiling Scores (PRCI-9 = 100)

Predictor Variable	β Coefficient	95% CI	p-value
Medical Records Officer role	5.8	1.90 – 9.70	0.004
4–5 years PHC experience	3.1	0.80 – 5.40	0.007
Knowledge-and-skills score	0.2	−1.60 – 2.00	0.84
Supportive supervision adequacy	0.4	−1.50 – 2.30	0.76

Source: Kogi State IMPACT End-of-Project HRH Survey.

Table 5C2 – Sensitivity Analyses Using Beta Regression (Bounded Outcome)

Predictor	β (scaled 0–1)	95% CI	p-value
MRO vs CHEW	0.065	0.025–0.105	0.002
4–5 years vs ≤3 years	0.036	0.011–0.061	0.004
Knowledge and skills	0.004	–0.003–0.011	0.24
Supportive supervision	0.009	–0.005–0.023	0.19
Constant	0.948	—	—
Pseudo R^2	0.041	—	—

Source: Kogi State IMPACT End-of-Project HRH Survey.