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Contributions of a community health worker program in improving district health system performance in South Africa, using routine health service variables in a quasi-experimental study design

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Abstract

Background Globally low- and middle-income countries are investing in community health worker (CHW) programs. These programs are viewed as fundamental to ensuring universal health coverage for all. Where CHW programs are doing what they should be doing and doing it adequately, they should make a difference in population health outcomes, reflecting health system changes.

However, there are not many studies exploring the contributions and effectiveness of large-scale, comprehensive community health worker programs on health system performance.

Methods This study takes place in the Ekurhuleni health district, in urban South Africa.

A before (pre) and after (post) intervention study (quasi-experimental) using routine health service variables (secondary data) from district clinics over nine years was conducted. Performance of intervention clinics with community health worker teams that had more than 60% population coverage were compared to similar control clinics that had no teams or teams with less than 30% coverage.

Results Both groups of clinics generally improved over time for routine health service variables for maternal, child health, infectious diseases, and cervical cancer programmes. Over nine years, intervention clinics showed more improved performance, statistically significant, in six health variables while controls improved in four. But importantly, intervention clinics improved proportionately better pre to post in seven of the nine (78%) variables studied compared to controls, demonstrating reduced diarrhoeal disease and pneumonia in children, better Vitamin A coverage, fewer severely malnourished children, better testing for HIV, and better screening for Tuberculosis and cervical cancer. Illustrating the comprehensive range of services provided by CHWs, the seven routine health service variables represented maternal, child health, infectious and non-communicable diseases. We also observed less uncontrolled hypertensive and diabetics in intervention clinics compared to control clinics.

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Conclusion Large-scale, sustained and comprehensive community health worker programs adequately covering populations contributed to improved urban district health system performance in Ekurhuleni, demonstrating their effectiveness. This was explored through improvements in health system performance over time. These findings, using routine health service variables, have policy implications for financial and other resource allocations in health districts in low- and middle-income countries.

Keywords Large-scale CHW program, Urban, Effectiveness, Health system performance, Health variables

Introduction

Globally low- and middle-income countries are increasingly investing in community health worker (CHW) programs. Such programs are viewed as fundamental to ensuring universal health coverage for all. Where CHW programs are functioning as they should be, they have the potential to improve health system performance and health outcomes. The type of CHW program, whether *comprehensive* and *large-scale*, or *selective* is an important consideration of their effectiveness. Most of the global evidence on effectiveness of CHW programs has relied on *selective* (disease-specific) approaches [1]. Not many countries having successfully introduced *comprehensive large-scale* CHW programs [2]. The *selective* approaches previously studied include those illustrating CHW contributions in reducing undernutrition in developing countries, primarily through early identification of at-risk children, advocating exclusive breastfeeding, provision of Vitamin A supplements, and supporting community-based supplementary feeding schemes [3]. CHWs have also successfully educated caregivers in good hygiene, use of bed nets, and in preparation of oral rehydration fluids and can reduce child mortality through early detection and management of common diseases such as pneumonia [4], diarrhea, and malaria [5]. CHWs support pregnant women during the antenatal and postnatal periods through health education, and routine check-ups of mothers and babies. CHWs also provide family planning education and support, are able to test and educate on HIV and screen for TB and other chronic conditions. Adherence support for common chronic conditions is another way CHWs improve health. It is clear that with the right support, *selective* CHW programmes play a vital role in household health education, screening, and disease management [6–9], however more studies are needed on the effectiveness of *comprehensive* CHW programs not just on population health outcomes but also on overall health system performance. The performance of a health system nationally or sub-nationally is often based on pre-determined measures of improvements in priority health conditions that the health system seeks to address.

In Ekurhuleni, an urban South African health district where this study was conducted, a large-scale *comprehensive* CHW program was introduced in 2010–11, at a time when this district had poor maternal and child

health outcomes and a high burden of HIV, TB, trauma and non-communicable diseases. CHWs were part of a national strategy to revitalize primary health care services in the 52 health districts in South Africa [10]. The national South African CHW program is a *comprehensive* CHW program addressing several priority health problems in the country and consists of over 70 000 CHWs; who work in teams of 6 to 10 supervised by a nurse team leader and linked to a local primary health care clinic (PHC). The CHWs have 9 to 12 years of schooling at the time of recruitment and are then later trained in-service for approximately three months on their activities. At the time of this study, most of the CHWs were recruited and employed on a contract basis either through a non-governmental organisation or a third party and paid a monthly stipend equivalent to the national minimum wage of USD 232 per month [11]. Each CHW is responsible for approximately 250 households in an area, regularly visiting them to provide basic health and social services and education aimed at changing behaviour. The nurse team leader either a registered nurse or a staff nurse is based in the local clinic and supervises, supports, manages and trains the CHWs [12]. The CHW program is thus able to complement existing primary health care services and help the health system respond to the priority health needs of local communities. In Ekurhuleni, with a population of four million people, most of whom are medically uninsured and vulnerable, the district CHW program of 1000 CHWs linked to 74 of the 95 district clinics, currently provides services to one million people in 280 000 households, so it is *large-scale*. The district was able to demonstrate that these CHW teams had a *comprehensive* scope and were functioning as intended, providing health education, early screening, adherence support, referrals, and other services across a range of health conditions (mother and child health issues, HIV, Tuberculosis and non-communicable diseases), and had been doing so for several years [11]. As part of our wider study we also found that these *comprehensive large-scale* services provided *long-term* were improving health outputs and outcomes in CHW supported households in Ekurhuleni, thus contributing towards improved population health outcomes in the urban district [12]. The served community in Ekurhuleni also reflected high acceptance and appreciation of the CHWs and their activities, confirming behaviour change towards more

healthier practices [13]. Through their unique positioning within communities and their team effort in changing health behaviour over time, these large-scale, comprehensive CHW programs can potentially promote health and prevent disease and contribute to enhancing health system performance.

PHC clinics cater to a specific catchment population and so where there is good population coverage with functional CHW teams providing *comprehensive* care and services, health improvements in the population could also contribute to improvements in routine health service variables at clinic level. This is a *measure* of district health system performance that could demonstrate the effectiveness of such CHW programs. While there are some studies in Brazil [14] and one in South Africa [15] that have used routine health data indicator sets at national and sub-national levels to determine CHW program performance; there is insufficient evidence on the effectiveness of *large-scale comprehensive* CHW programs over *longer* periods on health system performance, such as the one in Ekurhuleni, especially in the *urban* African context. Our study explores this gap.

Methods

The aim of this study was to assess the contributions of a large scale, comprehensive CHW program sustained over a long period towards improving district health system performance in South Africa. The study is set in an urban metropolitan district in South Africa, the Ekurhuleni health district.

A quasi-experimental pre and post intervention study using secondary health indicator data from district clinics over nine years (2010-11 to 2018-19) was conducted. Intervention clinics with community health worker teams with more than 60% population coverage of clinic catchment areas were matched and compared to similar control clinics that had no teams or teams with less than 30% population coverage; to determine changes in health system performance.

A District Health Information System (DHIS) routinely collects and reports on aggregates of identified health service and health performance variables from public health facilities in South Africa. The variables are rates whose denominator represents the catchment population of the relevant facility (Table 1). However, there are no specific clinic performance variables in the DHIS that directly reflect CHW program effectiveness. We, therefore, identified appropriate clinic-level performance measures that could *indirectly* reflect on the effectiveness of the services that CHWs in Ekurhuleni were providing. These routine health service measures benefited from the activities of the CHWs, and while the CHW program was not the only contributing factor, if the intervention clinics performed better, this could be attributed to the CHWs,

as the intervention and control clinics would be matched and there were no obvious confounders. The variables selected had to be related to the CHW activities of health education, social support, early health screening, referrals, diagnosis and retention or improvements in care. The health measures collectively also had to be representative of the *comprehensive* care provided by CHWs over a decade i.e. to encompass maternal, child health, infectious diseases, and non-communicable diseases (NCD).

Table 1 illustrates the 15 routine health service measures identified for the study, but we only used the nine where we had district data sets for the study period (Table 2). Due to the small values of some of these health measures such as pneumonia or diarrhoeal incidence, we converted seven of the nine measures into data elements, but Cervical Cancer screening and Tuberculosis start treatment were left as rates as raw data was not available for them in the DHIS for the study period. The rationale for a desired direction of change of a measure was based on the assumption that where CHWs were functioning as intended, intervention clinics would show improvements over time.

Study setting

The Ekurhuleni Health District, Gauteng Province, South Africa.

Study design

A before/pre (baseline) and after/post (end line) intervention study using secondary data from district clinics, 2010-11 to 2018-19. Routine health service data in South Africa was collected and analyzed over a financial year from April one year to March the following year. The pre intervention period was from 2010 to 11 to 2015-16 and the post intervention period was from 2016 to 17 to 2018-19.

Study sample

Ekurhuleni has three sub-districts; east, south, and north. In 2019, out of 95 PHC clinics in the district, 74 clinics had 177 CHW teams linked to them; the majority of these teams had been established and fully functional by 2016-17. Of the 74 clinics, six clinics in the district had more than 60% CHW coverage in their catchment areas and all were selected as the intervention sites; these six were from all three sub-districts. We selected two control clinics per intervention clinic to ensure stronger comparison and analysis; these had close socio-economic matches to intervention clinics but with only 0 to 30% population coverage by CHW teams. The control clinics were selected through the consensus of district management staff with expert knowledge of the clinics and communities served. In the real world setting of this study, we were not able to match for clinic size, resource capacity

Table 1 PHC clinic level mixed measures used to assess contributions of CHWs to the performance of Ekurhuleni health district

Health issues	Variable	Definition	Type of Variable: Indicator rate/ Data element	Numerator	Denominator	Desired good performance over the nine-year study period
1	Maternal Health	Antenatal (ANC) 1st Visit < 20 weeks rate	Rate	Antenatal 1st visit before 20 weeks	Antenatal 1st visit - total	Increase
2	Child Health	Pneumonia in child under 5 incidence rate	Rate	Children under 5 years newly diagnosed with pneumonia per 1,000 children under 5 years in the population.	Population under 5 years	Decrease
3		Diarrhea with dehydration in a child under 5 incidence rate	Rate	Children under 5 years newly diagnosed with diarrhoea with dehydration per 1,000 children under 5 years in the population	Population under 5 years	Decrease
4		Vitamin A dose 12–59 months coverage rate	Rate	Children 12–59 months who received Vitamin A 200,000 units, every six months as a proportion of population 12–59 months	Target population 12–59 months	Increase
5		Severe acute malnutrition under 5-year incidence rate	Rate	Children under 5 years newly diagnosed with severe acute malnutrition per 1,000 children under 5 years in the population.	Population under 5 years	Decrease
6	Infectious diseases	Human Immunodeficiency virus (HIV) tests done (number)	Data element	HIV tests done		Increase
7		Clients screened for Tuberculosis (TB) symptoms (number)	Data element	Clients screened for TB		Increase
8		TB clients older than 5 years start treatment rate	Rate	New TB clients started on drug susceptible tuberculosis (DS-TB) treatment as a proportion of all TB clients started on DS-TB treatment	All DS-TB treatment start	Increase
9	Non-communicable diseases	Cervical cancer screening coverage 30 years & older rate	Rate	Cervical smears in women 30 years and older as a proportion of the female population 30 years and older	[(80% women aged 30–59yrs)/10]+(20% women aged 20–59yrs)/3 + Cervical cancer screening 30 years and older]	Increase
10		Uncontrolled diabetes mellitus (DM) client (number)	Data element	Clients with uncontrolled diabetes		Decrease
11		Uncontrolled hypertension (HPT) client (number)	Data element	Clients with uncontrolled hypertension		Decrease
12		Client 40 years & older screened for DM (number)	Data element	Clients screened for DM		Increase
13		Client 40 years & older screened for HPT (number)	Data element	Clients screened for HPT		Increase
14		DM new client over 40 years detection rate	Rate	Newly diagnosed clients 40 years and older with a fasting blood glucose of > 7mmol/L or random blood glucose > 11.1 mol/L.	Population 40 years and older	Increase
15		DM new client under 18 years detection rate (annualized)	Rate	Newly diagnosed clients 18 years and older with a fasting blood glucose of > 7mmol/L or random blood glucose > 11.1 mol/L. initiated on treatment	Population 18 years and older	Increase

Table 2 PHC clinic level health measures used to assess contributions of CHWs to the performance of Ekurhuleni Health District

	Health issues	Variable	Definition	Type of Variable: Indicator rate/Data element
1	Maternal Health	Antenatal 1st visit before 20 weeks	Women who have a first visit before they are 20 weeks into their pregnancy	Data element (Number)
2	Child Health	Pneumonia new in child under 5 years	Children under 5 years newly diagnosed with pneumonia	Data element (Number)
3		Diarrhoea with dehydration new in child under 5 years	Children under 5 years newly diagnosed with diarrhoea with dehydration	Data element (Number)
4		Vitamin A dose 12–59 months	Children 12–59 months who received Vitamin A 200,000 units, every six months	Data element (Number)
5		Severe acute malnutrition in child under 5 years new	Children under 5 years newly diagnosed with severe acute malnutrition	Data element (Number)
6	Infectious diseases	Human Immuno-deficiency virus (HIV) tests done (number)	HIV tests done	Data element (Number)
7		Clients screened for Tuberculosis (TB) symptoms (number)	Clients screened for TB	Data element (Number)
8		New DS-TB treatment start rate	New TB clients started on drug susceptible tuberculosis (DS-TB) treatment as a proportion of all TB clients started on DS-TB treatment	Indicator/rate
9	Non-communicable diseases	Cervical cancer screening rate	Cervical smears in women 30 years and older as a proportion of the female population 30 years and older	Indicator/rate

or catchment populations. The choice of matching by socio-economic vulnerabilities was based on the view that this would be the major confounder on the effect of CHW interventions. Nonetheless, half the intervention clinics had similar catchment populations to the average of their two control clinics, at the start of the study (Supplementary Material 1). In terms of CHW team coverage of the catchment areas, a percentage was calculated by dividing the number of households covered by the CHW team by the number of households in the area. National census data on household size was used to determine number of households based on study clinic catchment populations.

Analysis

In the study period, annual average health indicator data was collected for each year in the period 2010-11 to 2018-19. 60% CHW team population coverage was attained in six intervention clinics by 2016-17. The years before the 60% coverage, 2010-11 to 2015-16, were considered the baseline/pre-intervention study period. The year in which 60% coverage was attained (2016-17) plus the subsequent years until 2018-19 were considered the end-line/post-intervention study period.

We calculated the median values using the annual average for each health indicator for the before (pre) and after (post) periods and used these in the statistical analyses. We computed proportionate changes in the median values across the respective clinics for each year and then for the pre and post intervention periods, per health indicator, across the intervention and control clinics. The

data for the two control clinics per intervention clinic were combined into one by calculating their medians for each year.

We assessed the study objective of determining if the CHW program contributed to improved district health system performance by describing the *pre and post* changes separately and then *pre to post* changes for each of the variables in the intervention and control clinics. We expect that both groups of clinics would show improvements in the post period and pre to post periods, but we expect that if the CHW program was effective, there would be higher pre to post differences in intervention clinics. By implication, this would show that the CHW program had contributed to health system performance at the clinic level; through positive efforts in improving population health in their catchment areas.

The non-parametric Mann-Whitney U test was used because of the small sample sizes and performed to test for differences in the medians of the intervention and control clinics. We set a two-sided alternative hypothesis to accommodate the directions of the variables; a significant *p*-value could therefore infer that either interventions performed better than controls, or vice versa. In the pre-period and separately for the post period, we compared the medians between intervention and control clinics. In the pre to post-period analysis, we compared medians between interventions clinics and the same was done for the control clinics. We also determined the proportionate differences in change in the *pre to post* periods between the two groups of clinics. However, it was not possible to run tests of statistical significance for

comparison of pre to post proportionate changes *between* intervention and control clinics, since we only had single percentage figures per health indicator studied.

In a controlled trial setting, intervention clinics with 100% CHW population coverage would have been randomly selected and compared to matched control clinics with no CHW coverage, and local context would not be relevant. However, the real-world setting of the study meant that most clinic catchment areas had some CHW coverage and it was not possible to proactively randomly assign clinics to the intervention and control groups. Without random sampling and with small samples, the use of statistical tests of significance and interpretation of *p*-values is challenging [16, 17]. In these instances and in health systems research, raising the level of statistical significance is often recommended [18]. Therefore for this study comparing intervention and control clinics the level of statistical significance (*p*-value) was set at 0.100.

The health variables used to determine effectiveness are a mix of indicators (rates) and data elements (raw data). Based on what was available in the DHIS for the study district, nine health measures were eventually used. The rates created a challenge for analysis, given the small number of clinics that met the inclusion criteria as intervention clinics. Therefore, where possible these health measures were converted to their data elements (raw data) for analysis; these applied to seven health measures; with two health measures remaining as rates, as shown in Table 2 below. These nine health measures of the initial 15 are primarily used to determine the statistical significance of effectiveness in the pre and post periods separately. The remaining six had their definitions and collection methods changed over the decade of the study period; data was therefore only available for a few years of the post period. We do describe some observed changes in the post-period for these six variables between the intervention and control clinics; but the focus below is on the nine health measures.

Results

This section describes changes in the nine health measures of clinic level performance over the nine years covered by the pre- and post-intervention period and compares proportionate and statistical changes between intervention and control clinics in the pre and post periods.

Table 3 compares the intervention and control groups in the pre and post periods respectively for the nine variables that had data available for the study period. The study findings are categorized by performance differences (either increased or decreased indicator values) between intervention and control groups for the pre-period and then for the post-period.

In Table 4 we list and compare pre to post changes in intervention clinics and control clinics. We also explore the percentage changes in the indicator values pre to post in both groups, and for each health indicator studied we also determined which group of clinics had better proportionate differences over the study period.

Performance differences between intervention and control clinics in the pre-period

For four of the nine variables, viz ANC 1st visit before 20 weeks, Vitamin A dose given at 12 to 59 months' age, HIV tests done and TB clients screened, intervention clinics started the pre-period at much lower levels compared to control clinics, (Table 3). For five other variables, viz. pneumonia and diarrheal disease under five years, severe acute malnutrition in children under five, the start of TB treatment in those older than five years of age, and cervical cancer screening, intervention clinics started the pre-period with better values compared to control clinics. In the pre-period, variable values in intervention clinics were significantly better than the control clinics for two variables viz. pneumonia and diarrheal disease incidence. In the same pre-period, control clinics started better than intervention clinics in five variables but showed better performance in three variables viz. ANC 1st visit before 20 weeks, Vitamin A coverage at 12 to 59 months, and HIV tests done being statistically significant.

Performance differences between intervention and control clinics in the post-period

When comparing post (end-line) performance changes between intervention and control clinics, (Table 3), a similar trend to the pre-period is observed. Intervention clinics had better performance in four variables compared to control clinics, with statistically significant changes for three of these viz. pneumonia and diarrheal disease incidence in children under five and cervical cancer screening. In the same post-period, control clinics were better than intervention clinics in five variables of which three showed significant differences viz. ANC 1st visit before 20 weeks, Vitamin A coverage at 12 to 59 months, and TB screening.

Pre to post performance differences in intervention and control clinics respectively

Table 4 illustrates the comparative analysis of pre to post period changes in intervention clinics and then in control clinics for the nine variables on child health, maternal health, communicable and non-communicable diseases for which full data was available for the study period. We found that intervention clinics showed statistically significant improvements pre to post in six health variables, viz. ANC 1st visit before 20 weeks, pneumonia and

Table 3 Comparative change in performance in the intervention and control clinics in pre and post periods respectively

Health Condition	Health measure	Type of Clinic	Median (Pre)	Intervention vs. control clinic changes in pre-period	Median (Post)	Intervention vs. control clinic changes in post-period
Maternal Health	ANC 1st Visit < 20 weeks (number)	Intervention	200.75	$p = 0.015$	287	$p = 0.100$
		Control	371.63		589.3	
Child Health	Pneumonia in Child under 5 incidence (number)	Intervention	20	$p = 0.026$	4	$p = 0.100$
		Control	76		87.25	
	Diarrhea with dehydration in a child under 5 incidence (number)	Intervention	3.75	$p = 0.009$	1	$p = 0.100$
		Control	13.25		4.75	
	Vitamin A dose 12–59 months (number)	Intervention	1634.5	$p = 0.004$	1903.5	$p = 0.100$
		Control	2822.38		3235.5	
Infectious diseases	Severe acute malnutrition under 5-year incidence (number)	Intervention	2.75	$p = 0.485$	2	$p = 0.700$
		Control	4.63		5	
	HIV tests done (number)	Intervention	545	$p = 0.002$	2910	$p = 0.400$
		Control	1198.25		4887.25	
	Clients screened for TB symptoms (number)	Intervention	1623.75	$p = 0.589$	35849.5	$p = 0.100$
		Control	5523.5		59,667	
Non-communicable diseases	TB clients older than 5 years start treatment rate	Intervention	92	$p = 0.899$	86.7	$p = 0.644$
		Control	89.3		93.95	
	Cervical cancer screening coverage 30 years & older rate	Intervention	55.1	$p = 0.202$	76.4	$p = 0.022$
		Control	41.8		49.3	

diarrhea incidence in under-fives, HIV tests done, clients screened for TB and cervical cancer screening. Controls improved significantly pre to post in four variables, viz. ANC 1st visit before 20 weeks, Vitamin A dose coverage at 12 to 59 months, HIV tests done and clients screened for TB. Performance was much better in intervention clinics compared to control clinics for pneumonia and diarrheal disease incidences in children under five. These variables were meant to decrease, and they decreased more steeply in intervention clinics. All nine health variables were related to activities undertaken by the CHW teams in their catchment areas.

Proportionate differences were determined by the percentage change in values pre to post for both intervention and control clinics separately. Looking at the proportionate change in differences pre to post for the nine variables for which pre and post data was available, intervention clinics showed higher percentage changes than control clinics in seven (78%) of the nine variables viz. pneumonia and diarrhoea incidence in children under five, Vitamin A dose coverage at 12 to 59 months, severe acute malnutrition in children under five, HIV tests done, TB clients screened and cervical cancer screening. Control clinics showed higher percentage changes than intervention clinics in two variables pre to post viz. ANC 1st visit before 20 weeks and TB start treatment of those older than five years (Table 4).

For the six variables of non-communicable diseases for which only post data was available (Variables 10 to 15 in Table 1); intervention clinics improved in two (fewer uncontrolled diabetes and hypertension cases); while control clinics improved in three, which were on screening and detection of diabetes and hypertension cases. The medians in the pre-period for five of the six variables of non-communicable diseases were not known.

Discussion

Outcome measures of health system performance of a public health program can help gauge impact on population health. Therefore, proving an intervention improved district health system performance, through the use of routine health service variables, is an important consideration for countries such as South Africa with limited health system resources, as it can guide resource allocation and prioritization to public health programs that are effective in improving population health.

This study represents a unique attempt to measure performance changes in intervention and control clinic variables over a long period of CHW team intervention in Ekurhuleni. However, as indicated by Habicht, Agarwal and their co-authors respectively [19, 20], it has been found that measuring effectiveness in a real-world setting poses many challenges. This study has tried to address a key methodological challenge by separating intervention

from control areas based on the proportion of households covered by CHWs and comparing them for significant differences in performance on suitable health variables identified from routinely collected data. The study also recognizes that *large-scale, long-term, comprehensive* CHW programs function in complex health systems where other factors can impact performance. However, by using the metrics of intervention clinic performance as variables of CHW effectiveness, based on a comparison with matched controls to eliminate confounders, this study has shown that CHWs do have a long-term positive impact on district health system performance.

This study used the clinic health program variables that are collected routinely to monitor district performance across South Africa, including Ekurhuleni. The Ekurhuleni district health variables at the clinic level on early antenatal care, maternal mortality, immunization, TB success rates, reduced loss to follow-up rates, and other variables have steadily improved over the last decade [21]. This study sought to determine whether the CHW program accelerated these improvements.

The question not really answered in the literature is whether a *comprehensive* (covers several health conditions), *large-scale, long-term* (sustained over a number of years) CHW program, such as the Ekurhuleni program is effective in improving clinic level performance. The clinics with good CHW coverage performed better than the control clinics which had poorer performance on seven out of nine variables, confirming that the CHWs were effectively contributing to improved health program performance and overall district health system performance.

Population coverage and proxy measures of effectiveness

Given the real-world setting of the study, with 74 of 95 district clinics with functional CHW teams, we could not select clinics that had 100% CHW coverage of the catchment population or controls with no coverage; we had to use what was available. We therefore compared performance of clinics serving areas with reasonable CHW team coverage (>60%) to clinics with low coverage (<30%) against proxy variables that would be suitable to measure CHW effectiveness. These indirect variables collectively demonstrate what the CHWs were effectively achieving for their communities. We showed previously that the district CHW teams were screening for early disease, promoting health and access to social services, and referring where appropriate [11]. We found that reasonable population coverage with effective CHWs resulted in improved clinic performance in the pre to post intervention period of our study.

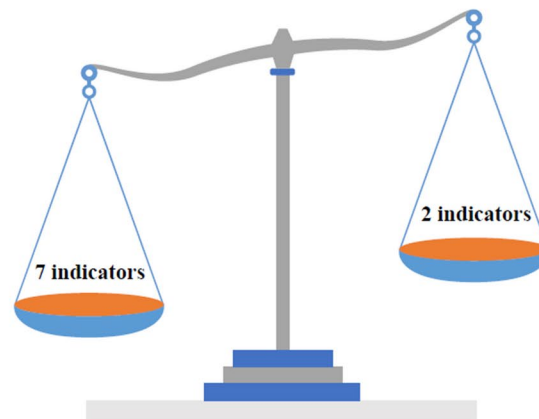
Over the study period, both intervention and control clinics showed improvements in clinic level variables. However, the crucial finding was the differences when we compared proportionate improvements between

Table 4 Pre to post comparative and proportionate changes in the intervention and control clinics

Health Condition	Health variable	Type of Clinic	Median (Pre)	Median (Post)	Comparative analysis Pre to Post	Proportionate differences Pre to Post	Comments
Maternal Health	ANC 1st Visit < 20 weeks	Intervention	200.75	287	$p = 0.024$	43%	Both groups of clinics improved pre to post, with intervention clinics starting with poorer levels in the pre-period. Control clinics improved better in the pre to post period.
		Control	371.63	589.3	$p = 0.024$	59%	
Child Health	Pneumonia in Child under 5 incidence	Intervention	20	4	$p = 0.024$	-80%	Numbers in intervention clinics declined significantly more in the post period. Control clinics did not perform well in the post-period. Intervention clinics started with better levels in the pre-period and were able to sustain the reductions better than the control clinics.
		Control	76	87.25	$p = 1.000$	15%	
	Diarrhea with dehydration in a child under 5 incidence	Intervention	3.75	1	$p = 0.095$	-73%	Both groups of clinics improved pre to post, with numbers in intervention clinics declining significantly more in the post-period compared to the control clinics
		Control	13.25	4.75	$p = 0.262$	-64%	
	Vitamin A dose 12–59 months	Intervention	1634.5	1903.5	$p = 0.167$	16%	Both groups of clinics improved pre to post, with intervention clinics starting with poorer levels in the pre-period; but still managing to do better than the control clinics in the pre to post period
		Control	2822.38	3235.5	$p = 0.095$	15%	
	Severe acute malnutrition under 5-year incidence	Intervention	2.75	2	$p = 1.000$	-27%	Numbers in intervention clinics declined significantly more in the post period. Control clinics did not perform well in the post-period. Intervention clinics started with better levels in the pre-period and were able to sustain the reductions better than the control clinics
		Control	4.63	5	$p = 0.714$	8%	
Infectious diseases	HIV tests done (number)	Intervention	545	2910	$p = 0.024$	434%	Intervention clinics started with poorer levels in the pre-period, but still managed to improve better than the control clinics in the pre to post period
		Control	1198.25	4887.25	$p = 0.024$	308%	
	Clients screened for TB symptoms (number)	Intervention	1623.75	35849.5	$p = 0.024$	2108%	Intervention clinics started with poorer levels in the pre-period, but still managed to improve better than the control clinics in the pre to post period.
		Control	5523.5	59,667	$p = 0.024$	980%	
	TB clients older than 5 years start treatment rate	Intervention	92	86.7	$p = 0.714$	-6%	Control clinics improved better in the pre to post period
		Control	89.3	93.95	$p = 0.548$	5%	
Non-communicable diseases	Cervical cancer screening coverage 30 years & older	Intervention	55.1	76.4	$p = 0.024$	39%	Both groups of clinics improved pre to post, but intervention clinics started with better levels in the pre-period and were able to significantly increase this more than the control clinics in the pre to post period
		Control	41.8	49.3	$p = 0.262$	18%	

Intervention clinics improved proportionately more than control clinics in:

1. Pneumonia incidence
2. Diarrhoeal disease incidence
3. Vitamin A coverage
4. Severe acute malnutrition
5. HIV tests done
6. TB screening
7. Cervical cancer screening



Control clinics improved proportionately more than intervention clinics in:

1. ANC first visit before 20 weeks
2. TB start treatment rate

Fig. 1 Summary of pre to post period health system improvements in nine health measures

intervention and control clinics. Although, in the main, both groups improved pre to post intervention; intervention clinics improved, proportionately better than controls for *seven* of nine of the variables representing measures in child health, infectious diseases and cervical cancer screening (as a measure for a non-communicable disease) (Fig. 1). This finding contributes to closing the gap in global evidence on the effectiveness of *large-scale, long-term, comprehensive* CHW programs in *urban* settings in developing countries.

Since the clinics were selected from all sub-districts in Ekurhuleni and the intervention clinics were each matched with two controls, the outcomes are considered due to the contributions of the CHW teams, rather than confounders, and the findings can be generalized to what is possible across the Ekurhuleni district when sub-districts increase their CHW team coverage.

Contributions to addressing priority health problems

A consideration of the different variables offer further insights into CHW program effectiveness in Ekurhuleni.

In some instances, such as with ANC 1st first visit before 20 weeks, Vitamin A doses at 12 to 59 months, HIV tests done and TB screening, intervention clinics had a much lower pre (baseline) level compared to their control clinics and therefore the CHWs had to work extra hard to reach control clinic performance levels and even exceed them, which they largely did, further demonstrating how CHW activities can change population health outcomes over time. Furthermore, even with a higher baseline for cervical cancer screening, services were sustained and performance increased in the intervention clinics in the post-period compared to the control clinics. We also observed that the control clinics had started with poorer baseline levels for pneumonia and diarrheal disease incidence, which may explain in part why they struggled to reduce these incidences, unlike in

the intervention clinics, where with the help of the CHW teams, they significantly reduced these cases.

Intervention clinics showed improved performance pre to post, compared to controls, in reducing diarrheal disease and pneumonia in children under five, better Vitamin A coverage, fewer severely malnourished children, better testing for HIV, better screening for TB and cervical cancer, and less uncontrolled hypertensives and diabetics; demonstrating the range of health conditions improved by the CHWs. Global evidence on studies of CHW effectiveness in other low and middle-income countries [2], including cost-effectiveness studies [22], have focused on *selective* disease-specific CHW performance. This study provides evidence that effectiveness can be achieved across several health conditions encompassed in a *comprehensive* CHW program such as the one in Ekurhuleni.

The findings of this study show significantly reduced incidence of common childhood illnesses such as pneumonia and diarrhoea in intervention clinics supported by CHWs. Immunization coverage remains a challenge in many urban informal settlements in developing countries [23] in areas similar to this study. We demonstrated in an earlier study that CHWs can address the challenge of achieving high immunization coverage in vulnerable communities through early screening and referrals of unimmunized children [11]. Those areas served by the CHWs benefited from the pneumococcal and the newer rotavirus vaccines which would have contributed to reducing the incidence of diarrheal diseases and pneumonia in young children as shown by Madhi and colleagues [24]. The CHW contributions are also in line with the findings of Bamford and co-authors who found that early child health screening contributed to improvements in immunization coverage and fewer children with diarrhoeal disease and pneumonia in South Africa [25]. The benefits shown in intervention clinic catchment areas

of reduced pneumonia and diarrhoeal diseases in young children is in line with case studies from other parts of Africa [26] that have shown that community health workers play a valuable role in improving child health screening and immunization coverage in communities.

Severe acute malnutrition in children under five is a concern in poor communities in South Africa, especially in big cities, due to rapid urbanization and migrant populations. Nationally, there appears to be a decline in the number of malnourished children, with Ekurhuleni performing better than many other districts with lower incidence, admissions and deaths from severe acute malnutrition. Severe acute malnutrition had halved by 2018–19 in Ekurhuleni [21], the time when the district had its most optimally functioning CHW teams and in line with our findings in intervention clinics. We postulate that this was due to improved health education on prevention of mother-to-child HIV transmission and the importance of exclusive breastfeeding in households. In addition to the health education, the early screening and referrals by CHWs to clinics in Ekurhuleni made a unique contribution to the improved performance pre to post in intervention clinics compared to control clinics, in a similar manner to what has been documented elsewhere [27]. In addition to these health-related activities, CHWs in Ekurhuleni made a significant difference in intervention households through social support activities by facilitating access to birth certificates and / or identity documents and helping families access social grants and food parcels [12], which according to Saloojee and co-authors are important to reduce social inequities [28] and consequently severe acute malnutrition. Bhutta and colleagues also found that the extra money and nutrition support [29] helps caregivers and mothers address nutritional challenges in their children.

Vitamin A coverage in children 12 to 59 months generally was higher in Ekurhuleni compared to national and provincial performance in 2018–19 [21]. CHWs in Ekurhuleni were not actively involved in providing Vitamin A to children in their households in the earlier years of implementation, due to the logistical challenges of carrying Vitamin A capsules at the time. These included keeping the capsules at the right temperature during household visits and having to snip and administer the capsules to a child. It was only included in their scope of practice in 2018–19, so, although intervention clinics performed slightly better than control clinics, pre to post, there was not sufficient time to judge CHW teams' effectiveness on this measure beyond improved clinic attendance. This could however be a suitable proxy indicator of CHW performance for the future, as shown by Perry and co-authors [30].

With regard to infectious diseases, over the years, both intervention and control clinics improved pre to post,

however, proportionately, intervention clinics improved more than control clinics for HIV testing and TB screening. This is an important contribution by CHWs through their household screening and education efforts, towards increasing awareness of HIV and TB status and early initiation of treatment. In addition, once on treatment, through regular follow-up they contributed towards improved adherence and better retention in care [12]. While intervention clinics maintained good TB start treatment rates in the post-period at higher than the national average [21], control clinics did slightly better for the same age group, viz. those over 5 years of age. We did not explore contextual management and/or operational challenges that may have influenced clinic capacity to deal with TB clients requiring treatment. In this study we have shown that there is better HIV & TB testing and screening by CHWs in households and referrals to clinics [12] and according to Shapiro [31] this can lead to improvements in HIV & TB outcomes. Cases of HIV defaulters and TB loss to follow-up were also increasing in many clinics, the reasons for which are not dealt with in our study, but as documented elsewhere, this could have been due to denial, stigma, and perceived poor quality of care in public sector facilities [32]. While the district CHWs did trace defaulters and contacts (primarily TB contacts) outside their allocated households, this was not done daily, since their allocated households had to be supported too. Others argue [33] that a *selective* health condition focus on conditions like TB could benefit TB defaulter and contact tracing outcomes, but in developing countries with limited resources, disease and/or activity-specific cadres may not be a sustainable option, nor the most cost-effective way of working. We have shown through this study that the provision of integrated, *comprehensive* outreach care in communities is more sustainable and effective in improving district health system performance and population health. Rather than introducing *selective* CHW programs, we suggest that increasing the numbers of CHWs that provide *comprehensive* care in health districts is preferable. It would provide support to more households, which then benefit in the long term from improved screening and testing for infectious diseases and tracing of contacts and defaulters and improved adherence support, ultimately reducing the overall number of clinic defaulters. This proposal is supported by the findings of Mwai and colleagues [34].

Studies show that given the increasing global and national [35] burden of non-communicable diseases (NCD), the role of CHWs in early screening, referrals, and treatment support for chronic diseases including non-communicable diseases is crucial. National district health variables especially for hypertension and diabetes changed during the study period with no data for several of the years prior to the introduction of the

district CHWs in the decade of the study. Early household screening and referrals of chronic diseases by CHWs are valuable mechanisms to reduce the burden from non-communicable diseases. Prince and co-authors found this was so especially as the population ages and lives longer [36]. In discussions with Ekurhuleni CHW teams, they reiterated that they felt they had better screening and adherence for chronic conditions in their supported households. We did find the same in CHW supported households [12], lending credibility to the findings in the post-period that the intervention clinics had fewer uncontrolled diabetes and hypertension clients viz. an average of 151 and 366 respectively, compared to 347 and 836 in control clinics. Much of the South African literature on the role of CHWs in adherence support focuses on HIV care, but in developed countries such as the USA, they [37] also showed the contribution CHWs make in assisting patients with diabetes and hypertension. Intervention clinics also showed better performance pre to post and significant improvements in cervical cancer screening (an important NCD measure) over the nine years, with a median cervical cancer screening rate of 76% in the post-period compared to 49% in control clinics. This study in Ekurhuleni emphasizes the important contributions to improved clinic NCD variables through sustained household support by district CHWs. This provides evidence that CHWs have the potential to reduce state costs of managing future diabetic and hypertensive complications in South Africa, supporting suggestions by others [38, 39].

Early household screening and testing for pregnancy by CHWs can improve early access to antenatal care. South Africa has seen a significant reduction in maternal and infant mortality [40] in the last decade or so, mostly due to its HIV program [41] and we suggest that national and sub-national efforts to improve early antenatal screening in clinics has also contributed to this. Early antenatal screening before 20 weeks for women in the intervention clinics improved significantly pre to post, but control clinics improved proportionately better than the intervention clinics. We postulate that since intervention clinics started at much lower pre-intervention levels compared to controls, this could be an important factor behind this finding. CHWs were referring pregnant women early to clinics and data from our earlier studies [11] shows that these clients were being seen and managed well in these clinics. Other studies have shown that CHWs have the potential to accelerate change by encouraging women to seek early pregnancy care. South Africa cannot afford to reduce maternal deaths slowly, every woman counts, so investing in more CHWs is still an expedient option to reduce maternal deaths, given that other studies have also shown similar benefits from community level initiatives such as home visits for health

education and supportive antenatal and post-natal care [42]. Early antenatal screening numbers remain a good proxy indicator for CHW effectiveness on maternal health in households.

Study limitations

We used a pre and post intervention study to determine changes to clinic level health variables. Such studies are commonly used for short-term periods, where there is less chance for contamination, confounders, and co-interventions. The rapid national scale-up of the CHW program in South Africa precluded experimental studies [43, 44]. All the control clinics had at least one CHW team, as there were no similar clinics in vulnerable areas in the district with no CHW teams. Pre-post study designs can suggest temporality where the intervention could have influenced certain outcomes, but they do not have control over other elements or events that are changing or happening at the same time as the intervention. This can be mitigated by measuring more than one health outcome, by introducing natural control clinics, and by sampling from all areas of the district. All these measures were included in our study and add elements of a quasi-experimental study design, meaning that any observed changes were most likely to be due to the CHW teams. The accuracy and quality of the multiple clinic level variables studied means that the data used was robust. We also could not find any flaws in the clinic level study design that would open the findings up to any other interpretation.

Each intervention clinic was matched with two control clinics serving communities similar in socio-economic vulnerabilities. The health system capacity in each clinic however was not used as a criteria for matching, as, based on the authors' experience and that of managers in the district the clinics were similar in terms of health system challenges such as human resources, drugs and other resources. Two control clinics were also selected for each intervention clinic as a form of mitigation in this regard.

As intervention clinics were found to have a lower baseline on several variables compared to control clinics, it could be argued that the outcome was because it was easier to make gains from a lower baseline. However, the CHW teams in the intervention clinics not only made these gains, but also exceeded and sustained them; including for those that were at higher baseline levels too. Further, even where control clinics had variables with poorer baseline levels, their performance remained low; reinforcing the finding that CHW teams made unique contributions to improving health system performance.

It is widely accepted that in health systems research, a p value of 0.1 is acceptable. In the methodology for this study objective we indicated that we used a p value of 0.1 instead of the common practice of 0.05. Others may

argue that the higher p value could weaken the interpretation of the results, however, we feel this is justified for studies of complex public health interventions in a real-world setting, such as this study. The p value of 0.05 that is the gold standard for clinical trials should not be assumed to be so for health service intervention studies [16, 17].

Ideally, we would have liked to have had a study where the intervention clinics had 100% CHW coverage and the control clinics had none. However, in the real world setting in the Ekurhuleni health district, this was not possible as services and interventions unfold over time. As such we had to define intervention clinics as those with 60% or more CHW coverage and control clinics as those with <30% coverage. While this is not a perfect distinction, the fact that we found intervention clinics had improved proportionately more than controls in 78% of the variables studied is powerful. Had the intervention clinic CHW teams covered a greater number of households and the controls fewer, the performance differences may have been even more magnified.

In South Africa, the district health information system (DHIS) captures health variables reflecting routine district performance. National Indicator Data Sets (NIDS) determine the health variables and data elements for which routine district data is collected. The NIDS are reviewed every three years nationally, and during the nine years of this study, the NIDS was reviewed three times. This resulted in some variables being added more recently (such as for NCDs), changed, or dropped completely, which prevented the inclusion of certain variables in this study. Therefore, while there are more variables and data elements per health condition, these could not be used in this study due to these changes. Immunization coverage rates were also excluded as a suitable proxy indicator of CHW effectiveness for this study due to changes in how these were calculated over the years in Ekurhuleni. As data is collected over time on these new or changed variables, a future study might be able to include more variables in a pre-post comparison. All variables that did not have these limitations and were related to CHW team activities were included. During the data verification and cleaning process, of the 15 health measures, only nine had data sets covering the entire study period, and even within these data sets, values were missing in some years and raw data was not available for two health measures. By combining several years into the Pre and Post periods respectively and using median values, the effect of the missing data was minimized. Over the years the study district had introduced data monitoring systems such as weekly, monthly and quarterly data verifications and inspections to address issues of data accuracy and quality, and therefore the nine clinic level measures extracted from the DHIS were the

best available data for the study in this real-world setting. The researchers are satisfied that even though we were limited to nine clinic level variables, these provided a sufficient number of diverse performance measures that could be used to assess effectiveness as they reflected the *comprehensive* nature of the CHW program activities.

Conclusion

The CHW program in Ekurhuleni, an *urban* district in South Africa, is a *large-scale comprehensive* program sustained for almost a decade in the district. Using clinic level routine health service variables as indirect measures of CHW performance, we demonstrated proportionately better health system improvements in child health, infectious diseases, and non-communicable diseases in areas with 60% or more CHW coverage compared to those with <30% coverage. The clinic level variables improved better in intervention than control clinics in seven of the nine health variables studied.

The proxy measures of effectiveness used in this study offer a way of determining the effectiveness of real world, sustained, large-scale, CHW programs in urban settings. The clinic level variables also demonstrate the comprehensive range of care provided and influenced by such programs. Other researchers could use this method to add to this largely new evidence to global knowledge on the effectiveness of *large-scale, sustained* and *comprehensive* CHW programs in *urban* settings. It also shows how important CHWs are in achieving universal health coverage and the sustainable development goals in LMICs.

Recommendations

1. While this paper's scope was not on the cost implications of CHW programs, it is important to note that CHW programs largely provide low cost [45, 46] preventative services compared to higher end curative care. Based on the authors' knowledge of public service salary levels in South Africa, currently a CHW in the province where this study was conducted earns approximately 650 USD per month, their nurse team leader OTL earns 950 USD per month. An entry grade doctor in the same health service earns approximately 4200 USD per month, with a professional nurse approximately 1400 USD per month respectively. CHW programs, which are relatively at a lower cost should be expanded to reach all households in Ekurhuleni and across all health districts in South Africa, with the necessary allocation of resources. The benefits do justify such a policy commitment.
2. Public health interventions utilize public funds and must yield beneficial and cost-effective results. Not enough evaluations of health programs are done

in the health services, especially in developing countries. We demonstrated that the CHW program in Ekurhuleni contributed to improved health system performance over time. More studies like this one are needed to show effectiveness of CHWs in a real-world setting. The ability to monitor and evaluate such large-scale and long-term programs must be developed and reinforced in district health services for continued investments in these programs.

- While the clinic level variables have proven to be suitable proxy measures of CHW program effectiveness, South Africa should also start collecting specific CHW program output and outcome variables as part of the district health information system. These could include numbers of clients screened by CHWs and referred, and who reported, and were linked back to care in PHC clinics for priority health conditions that include maternal and child health, HIV, TB and non-communicable diseases. Variables for social support services, such as food parcels distributed, civic documents and grants applied for could also be included.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

LT was responsible for data extraction and analysis. LT & EB developed the concepts, methodology, concluded the analysis and write-up. YP gave inputs and corrections to the final manuscript. JJ provided statistical support. All authors reviewed the manuscript.

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Data availability

The research data can be made available on reasonable request and/or after all related publications are concluded.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the University of Pretoria Faculty of Health Sciences Research Ethics Committee, Medical Campus, Tswelopele Building, Level 4–59. Ethics Reference No: 581/2018. This study adhered to the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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