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Inequalities in healthcare resources and outcomes threatening sustainable health development in Ethiopia: Panel data analysis

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Complete List of Authors:	Woldemichael, Abraha; Department of Health Management and Economics, School of Public Health, International Campus, Tehran University of Medical Science; School of Public Health, College of Health Sciences, Mekelle University, Takian, Amirhossein; Department of Global Health and Public Policy, School of Public Health, Tehran University of Medical Sciences; Health Equity Research Centre (HERC), Tehran University of Medical Sciences Akbari Sari, Ali; Department of Health Management and Economics, School of Public Health, Tehran University of Medical Sciences Olyaeemanesh, Alireza; Health Equity Research Centre (HERC), Tehran University of Medical Sciences; National Institute for Health Research

Keywords:	Ethiopia, Gini index, Healthcare outcomes, Healthcare resources, Inequality, Inequality decomposition

Inequalities in healthcare resources and outcomes threatening sustainable health development in Ethiopia: Panel data analysis

Abraha Woldemichael[1,2]; Amirhossein Takian[3,4*]; Ali Akbari Sari[5]; Alireza Olyaeemanesh[4,6]

About the Authors
Abraha Woldemichael, MSc, PhD candidate[1,2]
[1]Department of Health Management and Economics, School of Public Health, International Campus, Tehran University of Medical Sciences, Tehran, Iran
[2]School of Public Health, College of Health Sciences, Mekelle University, Mekelle, Ethiopia
Email: abrahaw2010@gmail.com
Phone: +989303579700

Amirhossein Takian, MD, PhD, FHEA[3,4*]
[3]Department of Global Health and Public Policy, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
[4]Health Equity Research Centre (HERC), Tehran University of Medical Sciences, Tehran, Iran
Email: takiana@gmail.com
Phone: +989121041412
* Corresponding Author

Ali Akbari Sari, MD, PhD[5]
[5]Department of Health Management and Economics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
Email: akbarisari@tums.ac.ir
Phone: +989127251294

Alireza Olyaeemanesh, MD, PhD[4,6]
[4]Health Equity Research Centre (HERC), Tehran University of Medical Sciences, Tehran, Iran
[6]National Institute for Health Research, Tehran, Iran
Email: arolyaee@gmail.com
Phone: +989124117610

Abstract:

Objective: This study was aimed at measuring inequalities in the distributions of selected healthcare resources and outcomes in Ethiopia from 2000 to 2015.

Methods: A panel data of all regions in Ethiopia was analysed to measure inequalities in the distribution of selected healthcare workforce, infrastructure, outcomes and finance. The analysis was based publicly available secondary data for the regions. The Theil and Gini indices, different Gini inequality decomposition models and Shapley post-estimation statistics were applied to quantify and characterise the inequalities. The analyses were performed using STATA version 14.

Results: Despite considerable inequality reductions between the baseline and end of study period, the Theil and Gini indices for the healthcare resources and some outcome indicators remained consistently high. The Gini for the healthcare workforce ranged from 0.428 for nurses and midwives to 0.704 for specialist doctors (SPDs). Inter-region inequality was highest for SPDs (95%) and lowest for health officers (54%). The Gini for hospital beds, hospitals and health centres were 0.592, 0.460 and 0.409, respectively, whilst the interaction term was highest for the health centres distributions (47.7%). There were inequalities in hospital outpatient department visit per capita (0.349) and fully inmunised children (0.307). The inequality in under-five mortality rate was increasing among regions overtime ($p = 0.048$). The overall Gini for government health expenditure per capita (GHE) was 0.596. The estimated relative GHE share of the healthcare workforce and healthcare infrastructure distributions were 46.5% and 53.5%, respectively. The marginal changes in the distribution of the healthcare resources were towards the advantaged populations.

Conclusion: This study revealed high inequalities in healthcare resources that are skewed to towards the advantaged populations among the regions. These inequalities hinder equal access to healthcare and achievement of healthcare outcomes. The government should strengthen monitoring mechanisms to address inequalities based on the national healthcare standards.

Keywords: Ethiopia, Gini index, Healthcare outcomes, Healthcare resources, Inequality, Inequality decomposition

Strengths and limitations of this study

- This study is of the first attempt to provide a comprehensive picture of the extent of inequalities in GHE, healthcare workforce, healthcare infrastructure and healthcare outcomes in Ethiopia.
- The application of different inequality measures and Gini inequality decomposition models helped to characterise the inequalities in healthcare resources and outcome in the decentralised health system.
- The estimated Shapley value GHE share of the selected explanatory variables indicated those healthcare resources that received priorities by the regional and central governments. The use of the multidimensional Gini inequality decomposition technique described the relative inequalities, marginal changes and the elasticity of the distributions analysed.
- This study has certain limitations. It used secondary data and the missing observations for some indicators were estimated from the annual average growth rate of the observations. The inequality decomposition change at two points in time cannot provide the whole information about the inequality trend. Besides, the analysis emphasised only the supply perspective of the health system. It did not analyse the demand perspective of the healthcare system.

Introduction

The concept of health has both moral, and right elements. The central objective of many health systems is to ensure health equity among populations. Health equity may be viewed as the absence of systematic differences in health among populations regardless of their social, economic, geographical, power and prestige aspects.[1–3] The guiding principle within this concept is equality of health[4] that may be achieved by making healthcare accessible and by addressing any socially unacceptable inequalities in healthcare that are amenable to policy decisions.[4–7] Thus, the principle of health equality begins with creating the opportunities to access healthcare and healthcare resources [2,8] while practicing of equal treatment of people with same healthcare needs regardless of their personal characteristics and ability to pay.[9,10]

Although the distinction between inequity and inequality is blurred and both can refer to unjust and socially unacceptable differences, the two concepts are not synonymous in the real world. This is because the application of normative judgements is inescapable in both cases.[7,11–13]

Inequity involves moral judgements about what is believed unjust and unfair. The unfair inequities due to avoidable causes can be viewed as a specific forms of inequality.[1,14–20] There are views that hold inequality as the quantitative description of the unfair differences from avoidable causes that do not belong to the legitimate occurrences due to individual responsibility.[20,21] However, the inequality concept itself is dynamic and open to different interpretations, and is highly linked to the socioeconomic structure of people.[22] In addition, any measure of inequality is subject to judgement about social welfare[15] and yet it may be perceived as a much broader concept that is commonly used in the field of human rights to describe differences among individuals, of which some could be unavoidable, at least with current knowledge and approaches.[23] The operational definition of inequality used in our study is the one suggested by Braveman who states that "*inequalities refer to differences in the distribution of resources or outcomes among people due to conditions that can be minimised or modified by policies*". [6]

The success of policies that are aimed at ensuring equality in healthcare is highly influenced by the political context[24], quality of information concerning the inequality[13,25–27] and the appropriateness of the actions for addressing identified unjust inequalities. Nevertheless, the government policies may favour the poor especially when the share of the private sector is minimal,[28] and the economic, political, moral, or practical aspects may be used as criteria for the allocation of resources.[20] Despite the unclear link between decentralisation and inequality, governments have been following decentralised policies to ensure social justice and address inequalities.[29,30] It is worth noting that the local governments in decentralised systems are likely to vary in power, boundaries, capacity, socioeconomic and demographic factors, living conditions and healthcare needs of their constituencies.[26,31,32] All these conditions indicate the complexity and the likely occurrence of inequality and the unavoidable nature of judgements from the concept of inequality.

Healthcare inequality is one of the conditions that hinder the success of healthcare systems and has been a concern to policymakers and planners. Little evidence is available regarding the extent of healthcare inequalities in the decentralised system of Ethiopia. Our study aims to measure inequalities in selected healthcare resources and outcomes from the year 2000 until 2015. The findings are anticipated to contribute to the better understanding of the effects of the existing health policies, provide information for action towards minimising unfair inequalities, contribute to policy decisions for strengthening the universal health coverage (UHC), and eventually contribute to achieve the sustainable development goals (SDGs) for health in Ethiopia and perhaps beyond.

Methods

Setting:

Ethiopia is a federal democratic country that consists of nine national regional states and two chartered cities (*henceforth regions*). According to the Central Statistical Agency (CSA) of Ethiopia, 80.6% of the total population for the year 2015 resided in rural areas. The geographic location of the regions, population proportions, other indicators for the year 2015 is presented in Fig.1.

Study design and data source

Panel data analysis was performed to measure inequalities in the distribution of selected healthcare resources and outcomes in Ethiopia. Panel data analysis allows better understanding of the trends and extent of inequalities in healthcare systems.[33] The panel was consisted of annual data for eleven regions from the year 2000 to 2015 and were related to total government health expenditure (GHE), healthcare workforce, healthcare infrastructure and healthcare outcomes. The data were retrieved from the annually published Health and Health Related Indicators (HHRIs) of Ethiopia and the Ethiopia Health and Demographic Survey (EDHS) reports of 2000, 2005, 2011 and 2016.[34–38]

Patient and public involvement

The study was based on data from the public domains and focused the supply perspective of the healthcare system. Thus, there was no direct patient or public involvement in the data collection and analysis. Ensuring fair allocation of human and material healthcare resources to people across the regions contribute to better healthcare outcomes. This study intends to answer the following three basic distributional inequality questions. The answers to the questions are expected to provide detailed understanding about the inequalities in healthcare and to seek solutions to the identified gap in the context of Ethiopia.

- Are the healthcare resources and outcomes fairly distributed across the regions in Ethiopia?
- What are the trends and extent of the overall inequalities in the selected distributions and which component (inter-region, between region, interaction term)

of the inequality dominantly contributes to the overall inequality of each distribution?

- Which healthcare resources have the dominant share of the GHE (are given more emphasis)? And what are the relative inequality, relative marginal change and elasticity the healthcare resource distribution with respect to the relative marginal change in the average GHE?

Variables (indicators)

The total government health expenditure (GHE) and total number of each selected health professional were considered the finance and healthcare workforce dimensions of the healthcare system. These dimensions vital for the proper function of the healthcare infrastructure. Therefore, total number of functional healthcare infrastructures (health centres, different levels of public hospitals together, and the public hospital beds) in each region were also healthcare resources related variables. The annual total of each variable in a region was ranked by the annual total population of that region. The ratios for were weighted by a fixed number of people for all the regions. The annual hospital outpatient department (OPD) visit per capita and the proportions of fully immunised children, and the EDHS five yearly reports on under-five child mortality rate (U5MR) and infant mortality rate (IMR) for each region were healthcare outcome related indicators.

The GHE is a crucial determinant of healthcare,[39,40] especially in countries like Ethiopia where the public sector is the main provider of the healthcare services. The missing data on GHE for the years 2013 and 2014 and on physicians for the year 2015 for all the regions were estimated using the annual average growth rate of each distribution. The five central hospitals in Addis Ababa, which are financed and managed by the Federal Government of Ethiopia, were included in the analysis for Addis Ababa region. The summary of the indicators used in the analysis is presented below.

Dimension	**Indicator**
Finance:	• Per capita GHE per annum
Healthcare workforce:	
	• General medical practitioner (GP) per 10,000 population [a]
	• Specialist doctor (SPD) per 10,000 population [b]
	• All physicians (APHYs) per 10,000 population [*]
	• Health officer (HO) per 10,000 population [c]
	• Nurses and midwives (NMWs) per 10,000 population [d]
	• Skilled health professionals (SKHPs) per 10,000 population [**]

- Pharmacy personnel (PHARP) per 10,000 population
- Medical laboratory personnel (MLABP) per 10,000 population
- Environmental health personnel (ENV'THP) per 10,000 population

Healthcare infrastructure:

- Health centre (HC) per 25,000 population
- Public hospital (HP) per 100,000 population
- Hospital beds (HPBs) per 10,000 population

Healthcare outcome:

- Hospital outpatient department (OPD) visit per capita
- Fully immunized children (FIMM) (%)
- U5MR per 1000 live births
- IMR per 1000 live births

* = a + b ** = a + b + c + d

Analysis and interpretation of inequality

We applied different methods to measure and decompose the inequalities. The Theil's index, one of the generalised entropy measures, was calculated to quantify the overall inequality of the distributions and reported Theil T (θ_T) and Theil L (θ_L). These measures were applied because they emphasise on different aspects of the same distribution. The θ_L (mean logarithmic deviation) is more sensitive to changes at the lower tail of a distribution, whilst θ_T is more sensitive to changes at the upper tail.[41–43] Despite the perfect decomposition of the Theil index into between and within-region inequality components, this technique hampers the re-ranking effect on the overall inequality of a distribution. Besides, the assumption of symmetric distribution with equal variance[44] was easily violated in our case because the regions are more likely to have differences in the distributions.

Furthermore, we calculated the Gini index (GI) of each distribution. The GI is one of the most commonly used measures of distributional inequalities in healthcare with respect to populations and is sensitive to differences in distributions about the middle. The GI is twice the area between the Lorenz curve (LC) and the 45-degree line of equality, and always assumes positive values ranging from zero (absolute equality) to one (absolute inequality).[45–50] The extent of the inequality was judged based on a five scale values categorised as absolute equality (GI < 0.2), high equality (GI = 0.2 to 0.3), inequality (GI = 0.3 to 0.4), high inequality (GI = 0.4 to 0.6) and absolute inequality (GI > 0.6).[51] This scale was used only to create simplicity of interpretation because the extent of inequality is context specific and can be judged differently.

We further applied different Gini decomposition techniques. First, the Pyatt's[52] overall Gini decomposition technique was applied to quantify the extent of inter-region or between-region Gini (G_B), within-region Gini (G_W) and the interaction pseudo-Gini (G_I) inequality components of each distribution. The sum of these components provides the overall Gini of a distribution. This analysis utilises the value of observations greater than zero. The interaction term (trans-variation, an overlap, or crossover term) is a re-ranking effect that occurs when the highest distribution in one region overlaps with the lowest distribution of the same variable in another region.[52–55] This method avoids the ambiguity that might arise from the interaction term in the Theil's index of inequality decomposition[52,56] and is more appealing to devise appropriate measures for reducing inequalities.[54]

Second, we calculated the extent of the overall inequality change between the baseline and end of study period using the Jenkins and Van Kerms'[57] decomposition of inequality changes at two points in time. Third, the Shapley post-estimation statistics was done after running the logarithm of the overall GHE (logGHE) per capita regression model on the explanatory variables (healthcare workforce and healthcare infrastructure indicators) to estimate their relative share of the overall GHE per capita.[58] This method uses the R-squared value of the regression model to precisely quantify the estimates by handling the problem that could arise from the residual. The estimates additively yield the overall GHE and point those variables that require explanations.[59–61] Finally, we applied the multi-dimensional decomposition of the overall GHE inequality (G_{GHE}) by the explanatory variables using the Lerman and Yitzhaki[62] method of decomposition as follows:

$$G_{GHE} = \sum_{k=i}^{K} R_k * G_k * S_k$$

where R_k is the Gini correlation of the ranked explanatory variable with the overall GHE, G_k is the Gini of the explanatory variable and S_k is the GHE share of the explanatory variable.

This technique incorporates the concept of concentration index and was used to quantify the relative marginal change, the relative GHE inequality, and the Gini elasticity of the explanatory variables with respect to the marginal change in the mean GHE and populations of the regions overtime. These measures enable us to properly explain the Gini of inequalities.[63,64] Bootstrap and Jackknife techniques were applied as appropriate to determine the 95% confidence interval (95%CI) for the indices.[65,66] All analyses were performed using STATA version 14. The interpretations and discussions of the findings were based on the Gini values.

Results

The Theil and Gini indices consistently revealed high overall inequalities in the GHE per capita, healthcare workforce, healthcare infrastructure and in some of the healthcare outcome indicators from the year 2000 to 2015 in Ethiopia. At least two of the three indices revealed values that have intersection points except for the indices for the SPDs and OPD visit per capita. Despite considerable reductions in the inequalities between the baseline and end of the study period in many of the healthcare resources analysed, there were strong Gini correlations between the overall GHE per capita and the distributions of the resources, and a relative marginal increase in the distributions of the resources with respect to a marginal increase in the mean GHE per capita towards the advantaged populations among the regions. The elasticity values of all the explanatory variables were less than one, suggesting the shortage of the healthcare resources. The net between-region (inter-region) inequality dominantly contributed to the overall inequality of distributions and the interaction term in all the distributions analysed was greater than zero.

Inequality in GHE

The overall Gini index for the GHE per capita (0.596) was very high, with values for the regions ranging from 0.317 for Harari to 0.624 for SNNP. The net inter-region inequality and the interaction term accounted for 54.4% and 37.9% of the overall GHE per capita inequality, respectively (Table 1).

Inequality in healthcare workforce

The overall Gini values ranged from 0.428 for nurses plus midwives to 0.682 for the SPDs (Table 1). Including zero values in the analysis of the time-series observations, the Gini for the SPDs was 0.704 (95%CI: 0.652 to 0.756). The net inter-region inequality ranged from 53.8% for the HOs to 95% for the SPDs, whilst the interaction terms was the lowest for the SPDs (1.6%) and the highest for the HOs (38.7%). Amhara (0.385) and Oromia (0.319) among the agrarian regions and Benshangul-Gumuz (0.368), Gambella (0.356), and Afar (0.323) among the pastoralist/semi-pastoralist regions had inequality in the SPDs. The inequality in the distribution of the HOs was a common issue to all the regions with absolute inequality in Somali (0.638) and Addis Ababa (0.633) regions. There were inequalities in nurses and midwives, and "skilled health professionals" in Somali and in all the agrarian regions except in Tigray. The pharmacy personnel in Gambella, and medical laboratory personnel in Benshangul-Gumuz and Harari regions were fairly equally distributed. There was inequality in the distribution of the environmental health personnel in Gambella and in the urban/urban dominated regions. Including zero observations in the analysis, the overall Gini values for pharmacy and environmental health personnel were 0.541(95%CI: 0.492 to 0.590), and 0.467 (95%CI: 0.402 to 0.531), respectively.

Table 1: National level Theil and Gini indices for GHE per capita and healthcare workforce and Gini index decomposition into its components and by region at 95% confidence interval for the indices from 2000 to 2015

Measure/ Region	GHE	GP	SPDs	APHYs	HO	NMWs	SKHPs	PHARP	MLABP	ENV'THP
Overall Index										
θ_L	0.707	0.643	1.066	0.711	0.708	0.345	0.360	0.590	0.440	0.377
	[0.566 to 0.848]	(0.524 to 0.763]	(0.951 to 1.181)	(0.619 to 0.803)	[0.604 to 0.812]	(0.289 to 0.402)	(0.306 to 0.414)	(0.454 to 0.726]	(0.380 to 0.501)	(0.282 to 0.471)
GI	0.596	0.591	0.682	0.612	0.577	0.428	0.437	0.539	0.491	0.457
	[0.544 to 0.648]	(0.545, 0.638)	(0.646, 0.718]	[0.578 to 0.646]	(0.544 to 0.610)	[0.393 to 0.463]	(0.402 to 0.473)	[0.484 to 0.593]	[0.457 to 0.524]	[0.399 to 0.515]
θ_T	0.645	0.653	0.864	0.682	0.572	0.299	0.313	0.517	0.414	0.388
	(0.511 to 0.779)	[0.517, 0.789]	(0.740, 0.988)	(0.578 to 0.786)	[0.499 to 0.646)	[0.247 to 0.351]	[0.261 to 0.366)	[0.397 to 0.636]	(0.351 to 0.476)	(0.256 to 0.521)
G decomp. (%)										
G_B	0.324 (54.4)	0.540 (91.3)	0.648 (95.0)	0.571 (93.3)	0.310 (53.8)	0.348 (81.4)	0.364 (83.2)	0.372 (68.1)	0.375 (76.5)	0.336 (73.5)
G_I	0.226 (37.9)	0.028 (4.6)	0.011 (1.6)	0.022 (3.6)	0.223 (38.7)	0.059 (13.7)	0.053 (12.1)	0.129 (24.9)	0.087 (17.7)	0.091 (19.9)
G_W	0.046 (7.7)	0.024 (4.1)	0.023 (3.4)	0.020 (3.2)	0.043 (7.5)	0.021 (4.9)	0.021 (4.7)	0.037 (7.0)	0.029 (5.8)	0.030 (6.6)
Overall GI	**0.596 (100)**	**0.591 (100)**	**0.682 (100)**	**0.612 (100)**	**0.577 (100)**	**0.428 (100)**	**0.437 (100)**	**0.539 (100)**	**0.491 (100)**	**0.457 (100)**
G deco. by Reg										
Agrarian										
TG	0.406	0.215	0.192	0.191	0.428	0.252	0.261	0.371	0.305	0.278
	[0.306 to 0.506]	[0.124 to 0.307]	[0 .070 to 0.315]	[0.117 to 0.264]	[0.329 to 0.527]	[0.183 to 0.322]	[0.195 to 0.327]	[0.277 to 0.464]	[0.249 to 0.361]	[0.197 to 0.360]
AM	0.590	0.206	0.387	0.228	0.492	0.331	0.337	0.439	0.385	0.161
	[0.508 to 0.672]	[0.136 to 0.276]	[0.281 to 0.493]	[0.174 to 0.282]	[0.386 to 0.597]	[0.288 to 0.373]	[0.293 to 0.380]	[0.304 to 0.574]	[0.314 to 0.455]	[0.055 to 0.266]
OR	0.562	0.192	0.319	0.158	0.462	0.345	0.339	0.415	0.384	0.212
	[0.473 to 0.651]	[0.097 to 0.286]	[0.193 to 0.444]	[0.099 to 0.218]	[0.358 to 0.567]	[0.292 to 0.397]	[0.294 to 0.384]	[0.326 to 0.504]	[0.287 to 0.482]	[0.174 to 0.250]
SNNP	0.624	0.183	0.269	0.164	0.496	0.342	0.340	0.449	0.323	0.165
	[0.526 to 0.722]	[0.134 to 0.232]	[0.207 to 0.330]	[0.107 to 0.221]	[0.406 to 0.585]	[0.276 to 0.408]	[0.275 to 0.405]	[0.329 to 0.570]	[0.257, 0.388]	[0.084 to 0.246]
Pastoral/Semi-pastoral										
SO	0.555	0.117	0.187	0.100	0.638	0.384	0.383	0.509	0.359	0.259
	[0.464 to 0.647]	[0.073 to 0.162]	[0.125 to 0.249]	[0.076 to 0.125]	[0.435 to 0.841]	[0.326 to 0.442]	[0.316 to 0.450]	[0.405 to 0.614]	[0.298 to 0.421]	[0.157 to 0.361]
AF	0.436	0.171	0.323	0.158	0.407	0.246	0.242	0.392	0.363	0.192
	[0.372 to 0.499]	[0.136 to 0.206]	[0.223 to 0.424]	[0.112 to 0.203]	[0.341 to 0.474]	[0.199 to 0.294]	[0.194 to 0.289]	[0.309, to 0.474]	[0.276 to 0.449]	[0.035 to 0.349]
BG	0.493	0.270	0.368	0.238	0.360	0.179	0.177	0.386	0.242	0.209
	[0.429 to 0.557]	[0.184 to 0.357]	[0.248 to 0.487]	[0.148 to 0.328]	[0.293 to 0.426]	[0.132 to 0.226]	[0.137 to 0.217]	[0.301 to 0.471]	[0.184 to 0.301]	[0.106 to 0.313]
GA	0.511	0.290	0.356	0.207	0.360	0.181	0.180	0.224	0.384	0.316
	[0.447 to 0.575]	[0.201 to 0.379]	[0.233 to 0.478]	[0.130 to 0.284]	[0.293 to 0.427]	[0.083 to 0.278]	[0.095 to 0.266]	[0.117 to 0.330]	[0.308 to 0.461]	[0.219 to 0.414]
Urban/urban dominated										
HA	0.317	0.281	0.197	0.187	0.483	0.169	0.157	0.427	0.276	0.485
	[0.252 to 0.381]	[0.193 to 0.370]	[0.122 to 0.271]	[0.110 to 0.264]	[0.343 to 0.622]	[0.096 to 0.241]	[0.086 to 0.228]	[0.322 to 0.531]	[0.186 to 0.365]	[0.175 to 0.795]
AA	0.547	0.323	0.300	0.295	0.633	0.281	0.275	0.432	0.344	0.436
	[0.447 to 0.646]	[-0.000 to 0.647]	[0.159 to 0.442]	[0.146 to 0.444]	[0.494 to 0.771]	[0.230 to 0.332]	[0.228 to 0.321]	[0.324 to 0.540]	[0.282 to 0.407]	[0.347 to 0.525]
DD	0.606	0.193	0.208	0.174	0.531	0.233	0.225	0.442	0.309	0.362
	[0.509 to 0.703]	[0.139 to 0.247]	[0.138 to 0.277]	[0.107 to 0.242]	[0.422 to 0.639]	[0.191 to 0.276]	[0.188 to 0.262]	[0.345 to 0.539]	[0.236 to 0.382]	[0.183 to 0.540]

Inequality in healthcare infrastructure

The overall Gini for the health centres, public hospitals, and hospital beds distribution, and the net between-region inequality of the same distributions accounted for 0.409, 0.460 and 0.592, and 45%, 94%, and 92% of the overall inequality of each distribution, respectively (Table 2). The interaction term was the highest for the health centres distributions (47.7%). The health centres were equally distributed only in Benshangul-Gumuz (0.223), Harari (0.290) and Addis Ababa (0.242) regions. The Gini values for the hospitals and hospital beds distributions were less than 0.3 in all the regions except the statistically insignificantly high Gini values for hospital beds in Somali and in SNNP regions. The regional disparities in the distributions of selected healthcare resources is graphically illustrated in Fig. 2. For example, the bottom 50%, middle 40% and top 10% of the populations in Tigray had access to 31.2%, 50.5% and 18.3% of the total nurses and midwives in the region, respectively.

Inequality in healthcare outcomes

The hospital OPD visit per capita (0.349) and fully immunised children (0.307) revealed inequality. The net between-region inequality of the same indicators accounted for 75.1% and 59% of the overall inequality of each indicator, respectively (Table 2). The Gini values for OPD visit per capita in Afar (0.341) and Gambella (0.427), and for the fully immunised children in Somali (0.524), Afar (0.393) and Benshangul-Gumuz (0.311) regions were higher than the values in the other regions. The net between-region inequality of the under five children and infant mortality rates accounted for about 47% and 50% of the overall inequality of each indicator, respectively.

Table 2: National level Theil and Gini Indices for healthcare infrastructure and outcomes and Gini decomposition into its components and by region at 95% confidence interval for the indices from 2000 to 2015

Measure/Region	Healthcare infrastructure			Healthcare outcomes			
	HCs	**PHPs**	**HPBs**	**OPD**	**FIMM**	**U5MR**	**IMR**
Overall Index							
θ_L	0.310	0.362	0.673	0.239	0.264	0.072	0.046
	[0.268 to 0.351]	[0.279 to 0.444]	[0.593 to 0.752]	[0.195 to 0.283)	[0.175 to 0.352]	[0.048 to 0.096]	(0.026 to 0.067]
GI	0.409	0.460	0.592	0.349	0.307	0.208	0.163
	(0.380, 0.439)	(0.404, 0.517]	(0.563, 0.621)	[0.321 to 0.377]	[0.269 to 0.345]	(0.175 to 0.241)	[0.130 to 0.195]
θ_T	0.274	0.419	0.616	0.196	0.166	0.068	0.043
	(0.234 to 0.314)	(0.310 to 0.527]	(0.540 to 0.693]	[0.164 to 0.228)	[0.124 to 0.209]	[0.047 to 0.089)	[0.025 to 0.062)
Gini decomp. (%)							
G_B	0.183 (44.7)	0.433 (94.0)	0.545 (92.1)	0.262 (75.1)	0.181 (59.0)	0.098 (47.1)	0.081 (49.5)
G_I	0.195 (47.7)	0.014 (3.1)	0.034 (5.7)	0.069 (19.7)	0.105 (34.2)	0.095 (45.7)	0.068 (41.5)
G_W	0.031 (7.6)	0.013 (2.9)	0.013 (2.2)	0.018 (5.2)	0.021 (6.8)	0.015 (7.2)	0.015 (9.0)
Overall GI	**0.409 (100)**	**0.460 (100)**	**0.592 (100)**	**0.349 (100)**	**0.307 (100)**	**0.208 (100)**	**0.163 (100)**
G decomp. by region							
Agrarian							
TG	0.380	0.080	0.089	0.084	0.061	0.209	0.198
	[0.330 to 0.431]	[-0.029 to 0.190]	[-0.011 to 0.190]	[0.061 to 0.107]	[0.025 t to 0.096]	[0.057 to 0.362)	(0.080 to 0.316)
AM	0.432	0.108	0.131	0.214	0.210	0.160	0.109
	[0.341 to 0.524]	[-0.011 to 0.227]	[0.015 to 0.248]	[0.121 to 0.307]	[0.146 to 0.273]	(0.082 to 0.239)	[0.069 to 0.149)
OR	0.419	0.142	0.149	0.155	0.231	0.175	0.129
	[0.340 to 0.498]	[0.113 to 0.172]	[0.017 to 0.281]	[0.082 to 0.228]	[0.164 to 0.298]	[0.021 to 0.329]	[0.063 to 0.195)
SNNP	0.339	0.159	0.598	0.146	0.250	0.157	0.129
	[0.304 to 0.373]	[0.061 to 0.258]	[-0.185 to 1.380]	[0.090 to 0.202]	[0.150 to 0.350]	(0.052 to 0.263)	(0.058 to 0.199]
Pastoral/Semi-pastoral							
SO	0.493	0.051	0.314	0.197	0.524	0.153	0.099
	[0.426 to 0.561]	[0.037 to 0.065]	[-0.120 to 0.748]	[0.113 to 0.281]	[0.384 to 0.665]	[0.015 to 0.290)	[0.051, 0.146)
AF	0.427	0.186	0.219	0.341	0.393	0.132	0.088
	[0.354 to 0.500]	[0.156, 0.217]	[0.099, 0.340]	[0.249 to 0.432]	[0.219 to 0.566]	(-0.073 to 0.338)	[0.048, 0.128)
BG	0.223	0.113	0.118	0.147	0.311	0.125	0.145
	[0.168 to 0.278]	[0.077 to 0.149]	[0.082 to 0.155]	[0.102 to 0.192]	[0.217 to 0.405]	(-0.004 to 0.255)	(0.038 to 0.252)
GA	0.308	0.161	0.143	0.427	0.293	0.195	0.115
	[0.262 to 0.354]	[0.081 to 0.241]	[0.095 to 0.191]	[0.303 to 0.550]	[0.189 to 0.397]	[0.061 to 0.329)	[0.073 to 0.157)
Urban/urban dominated							
HA	0.290	0.197	0.122	0.223	0.133	0.199	0.132
	[0.244 to 0.336]	[0.114 to 0.281]	[0.069 to 0.174]	[0.165 to 0.282]	[0.079 to 0.186]	(0.001 to 0.397)	[0.069 to 0.194]
AA	0.242	0.052	0.103	0.152	0.220	0.219	0.193
	[0.150 to 0.335]	[0.023 to 0.081]	[0.078 to 0.128]	[0.070 to 0.234]	[0.133 to 0.308]	[0.074 to 0.365)	[0.091 to 0.294)
DD	0.327	0.106	0.102	0.274	0.279	0.143	0.107
	[0.241 to 0.413]	[0.039 to 0.173]	[0.056 to 0.149]	[0.177 to 0.371]	[0.168 to 0.389]	[0.064 to 0.223]	[0.067 to 0.146)

The Gini decomposition of inequality change between the baseline and end of study period indicated a 31.2% reduction in the inequality of the overall GHE per capita ($p = 0.030$) (Table 3). The inequality in the GPs, all physicians, HOs, nurses plus midwives, “skilled health professionals”, and medical laboratory personnel distributions each reduced by more than a third ($p < 0.01$). The inequality reductions for the SPDs, pharmacy personnel and environmental health personnel distributions were statistically insignificant ($p > 0.05$). The inequalities in the distributions of the health centres and the coverage of fully immunised children reduced by 60.3% and 63.8% (p < 0.001), respectively. The inequality in U5MR among the regions showed 64.5% increase (P = 0.048).

Table 3: Overall Gini Decomposition of inequality change between the years 2000 and 2015 at 95% bootstrap confidence interval for the inequality change

Indicator	Gini Index, (95%CI) Year 2000	Year 2015	Change (Δ) Δ, (95% CI)	Δ (%)	P-value
Finance					
Per capita GHE	0.446 [0.324 to 0.567]	0.307 [0.238 to 0.376]	-0.139 [-0.265 to -0.014]	- 31.2	0.030
Healthcare workforce					
GPs	0.560 [0.323 to 0.798]	0.364 [0.219 to 0.510]	-0.196 [-0.316 to -0.076]	- 35.0	0.001
SPDs	0.679 [0.485 to 0.873]	0.637 [0.463 to 0.812]	-0.042 [-0.177 to 0.093]	- 6.2	0.543
APHYs	0.581 [0.415 to 0.746]	0.355 [0.251 to 0.460]	-0.226 [-0.366 to -0.085]	- 38.8	0.002
HOs	0.461 [0.345 to 0.577]	0.288 [0.206 to 0.370]	-0.173 [-0.292 to -0.054]	- 37.5	0.004
NMWs	0.433 [0.320 to 0.546]	0.269 [0.144 to 0.393]	-0.164 [-0.262 to -0.066]	- 37.9	0.001
SKHPs	0.448 [0.305 to 0.592]	0.277 [0.160 to 0.393]	-0.172 [-0.263 to -0.081]	- 38.3	0.002
PHARP	0.492 [0.349 to 0.636]	0.409 [0.261 to 0.556]	-0.084 [-0.215 to 0.047]	- 17.0	0.210
MLABP	0.519 [0.220 to 0.819]	0.315 [0.116 to 0.514]	-0.204 [-0.315 to -0.094]	- 39.3	0.000
ENV'THP	0.450 [0.252 to 0.648]	0.378 [0.219 to 0.536]	- 0.072 [-0.204 to 0.060]	-16.0	0.284
Healthcare Infrastructure					
HCs	0.313 [0.156 to 0.470]	0.124 [0.021 to 0.227]	-0.189 [-0.242 to - 0.136]	- 60.3	0.000
PHPs	0.506 [0.134 to 0.879]	0.523 [-0.096 to 1.141]	0.016 [-0.146 to0.179]	3.2	0.843
HPBs	0.541 [0.444 to 0.639]	0.444 [0.224 to 0.663]	-0.098 [-0.310 to 0.115]	- 18.0	0.367
Healthcare outcomes					
OPD visit	0.343 [0.242 to 0.445]	0.294 [0.160 to 0.428]	-0.050 [-0.141 to 0.042]	- 14.4	0.286
FIMM	0.408 [0.264 to 0.553]	0.148 [0.064 to 0.232]	-0.261 [-0.392 to -0.130]	- 63.8	0.000
U5MR	0.082 [0.022 to 0.142]	0.135 [0.046 to 0.224]	0.053 (0.0004 to 0.105]	64.5	0.048
IMR	0.075 [0.027 to 0.123]	0.117 [0.031 to 0.202]	0.041 (-0.015 to 0.097]	54.6	0.150

The estimated Shapley value of the relative overall GHE share of the healthcare workforce and healthcare infrastructure distributions accounted for 46.5% and 53.5%, respectively. The relative shares were higher for the health officers (18.09%), nurses plus midwives (17.20 %), medical laboratory personnel (10.65%), pharmacy personnel (9.58%) and health centres (32.32%) (Table

4). As shown in column three of Table 5, these variables were also strongly correlated with the overall GHE inequality. Column five and seven show the relative GHE inequality and the Gini elasticity of all the variables in the model with respect to the relative change in the mean GHE per capita. The elasticity for all the variables were less than one.

Table 4: Estimated Shapley value of overall logGHE share of selected healthcare resources in Ethiopia from 2000 to 2015.

Factor	Estimated Shapley value of GHE share of selected healthcare resources				
	Value	**%**		**Value**	**%**
GPs	0.0173	2.24	Group 1	**0.3594**	**46.48**
SPDs	0.0155	2.01			
HOs	0.1398	18.09			
NMWs	0.1330	17.20			
PHARM	0.0741	9.58			
MLABP	0.0823	10.65			
ENVTP	0.0171	2.21			
HCs	0.2499	32.32	Group 2	**0.4138**	**53.52**
HPs	0.0198	2.57			
HPBs	0.0242	3.13			
Total	**0.7731**	**100.00**		**0.7731**	**100.00**

The highest and lowest relative GHE inequality and Gini elasticity were for the HOs (0.8525 vs. 0.8513) and environmental health personnel (0.3750 vs. 0.3612), respectively. The relative marginal change in the average GHE resulted in a relative marginal increase in the distributions of all the variables (column six) towards the privileged people among the regions (the negative sign indicated the concentration of the indicator among the advantaged populations). Ceteris paribus, a one percent increase in the GHE per capita resulted in a 0.0027 percent increase in the distribution of the GPs towards the most affluent people among the regions.

Table 5: Relative marginal effects of overall GHE inequality and elasticity of selected healthcare resources overtime in Ethiopia from 2000 to 2015.

Explanatory Variable (K_i)	GHE Share (S_k)	Gini of Component (G_k)	Correlation with GHE (R_k)	Share of GHE Inequality (I_k) = (R_k * G_k * S_k)/G	Relative GHE Inequality (I_k/S_k)	Relative marginal change (I_k-S_k) %, [95% bootstrap CI]	Elasticity (η_k) = (R_k * G_k)/G
GPs	0.0048	**0.5913**	**0.4430**	0.0021	**0.4375**	**-0.0027** [-0.0036 to -0.0018]	**0.4395**
SPDs	0.0026	**0.7036**	**0.4032**	0.0013	**0.5000**	**-0.0014** [-0.0019 to -0.0008]	**0.4760**
HOs	0.0061	**0.5771**	**0.8792**	0.0052	**0.8525**	**-0.0009** [-0.0013 to -0.0005]	**0.8513**
NMWs	0.0674	**0.4281**	**0.7967**	0.0386	**0.5727**	**-0.0288** (-0.0340 to -0.0237]	**0.5723**
PHARM	0.0082	**0.5413**	**0.8166**	0.0061	**0.7439**	**-0.0021** [-0.0027 to -0.0015]	**0.7417**
MLABP	0.0093	**0.4909**	**0.8061**	0.0062	**0.6667**	**-0.0031** (-0.0038 to -0.0025)	**0.6640**
ENV'TP	0.0040	**0.4665**	**0.4615**	0.0015	**0.3750**	**-0.0026** [-0.0033 to -0.0018)	**0.3612**
HCs	0.0068	**0.4092**	**0.8107**	0.0038	**0.5588**	**-0.0030** (-0.0036 to -0.0024]	**0.5566**
HPs	0.0109	**0.4605**	**0.5459**	0.0046	**0.4220**	**-0.0063** (-0.0076 to -0.0050)	**0.4218**
HPBs	0.0764	**0.5920**	**0.4889**	0.0371	**0.4856**	**-0.0393** (-0.0511 to -0.0275]	**0.4856**
Total G_{GHE}		**0.5960**					

Discussion

This study analysed the trend and degree of inequalities in the distributions of selected healthcare resources and outcomes in Ethiopia over sixteen years period from 2000 to 2015. Different approaches were used to describe and characterise the inequalities. The between-region, within-region, and the overlap inequality component of the overall Gini of each distribution was calculated. The decomposition of inequality changes between the baseline and end of study period, and the overall GHE share of the healthcare resources were estimated. The relative marginal changes in the inequalities of the healthcare resources with respect to the marginal increase in the mean overall GHE per capita were determined. Our findings revealed high degree of overall inequality for most of the distributions analysed. The net between-region GHE inequality accounted for 54% of the overall inequality in the GHE per capita. Evidence shows that better economic position of a country and sufficient GHE can positively influence health system outcomes.[67] In the under-resourced countries, decentralisation may lead to more inequalities among regions.[68] The high inequality in the GHE across the regions in our study could be a consequence of multiple factors including the regional differences in emphasis to healthcare, development priorities or compliance to the general health policies of the country.[69] Like the report from other studies, small allocation of GHE, difference in roles of the regional governments with respect to their spending on health,[70] regional difference in per capita GDP and weak balancing mechanisms [40,71] could have contributed to the high degree of inequalities in GHE in our findings.

The reduction in GHE inequality reflected in our study may imply an increased governments' commitment of spending more on health,[72–74] improvements in governance [75,76] or increased commitment of the development partners to health. Nevertheless, the overall inequality remained too high and sufficient enough to contribute to the inequalities in healthcare among the regions. Our findings indicated strong correlation of the overall GHE inequality with inequalities of some of the healthcare resources. The success of healthcare depends on the rational distribution of both human and material resources.[77] Others also reported that regions with a better capacity to use the health budget had better opportunities to receive, allocate and spend more finances to expand the healthcare infrastructure and staff to healthcare facilities.[78]

A region with a high density of the healthcare workforce can be in a better position to serve the healthcare needs of its people than a region with a low density of healthcare workforce.[42] The high national level inequalities in the healthcare workforce and the high net between-region inequalities in our findings, might reflect an overall shortage of the healthcare workforce in the entire healthcare system[79] or maldistribution of the limited healthcare workforce that might have provided a chance of healthcare access mainly to the limited number of urban people. The inequality in the distributions of the GPs and nurses plus midwives in our study were more than thrice (0.591 vs. 0.191) and about twice (0.428 vs. 0.267), respectively when compared to that reported from China.[80] Again, the inequality in "All physicians" distribution was also nearly twice (0.612 vs. 0.331) that reported from a study in Japan.[81] The relatively homogenous and small Gini values for "All physicians" across the regions in our study may indicate the phenomenon of a hidden inequity.[23] A recent study reported turnover of specialist doctors in Ethiopia ranging from 21.4% in Dire Dawa to 43.3% in Amhara regions and the destination for the majority was claimed to be Addis Ababa.[82] However, like in the other regions our findings indicated that Addis Ababa had significant inequality in the distribution of the SPDs. This skewed distribution may imply the shortage of the SPDs due to self-employment or working for the private sector.

The marked reduction in the inequality of the health centres distributions (60.3%) in our study indicate the efforts of the central and regional governments to improve access to primary healthcare for the majority of the rural residents.[83] Nevertheless, the increasing tendency in the inequality of the hospitals distribution in our findings may imply an increasing inequality in the healthcare workforce, especially among the physicians including the SPDs. Similarly, others also found a wide disparity in the geographic distribution of healthcare workforce, health facilities and hospital beds.[84] The high inequalities in the distributions of the healthcare infrastructure indicators analysed in our study might inform regional differences in management, institutional capacity, priorities and strategies followed to meet the healthcare needs of their local people.

Statistically significant but numerically small relative marginal increases in the allocation of the healthcare workforce and healthcare infrastructure towards the advantaged people among the regions with respect to a marginal increase in the average GHE overtime were observed. In contrast, evidence from a developed decentralised system showed reduction in inequalities among regions.[85] The less than one Gini elasticity value for each of the healthcare resource indicators in our study implies that the resources are yet necessary inputs to all the regions.[40]

The fact that the majority of Ethiopians are rural residents and the inequalities remained very high, challenge the uniform achievement of the health sector goals in the country. As it is stated by Atkinson *"a smaller cake more fairly distributed may be preferable to a bigger one with high levels of inequality"*.[22] The high inequality in the GHE across the regions identified in our study makes the issue of inequalities of other human and material healthcare resource more challenging as they are dependent upon the total government health spending. Thus, while minimising the existing inequalities among the regions is crucial, the success may depend not only on the commitment of the governments to improve the financial, human and material resources allocations but also on the identification of other context specific opportunities and barriers to reduce the inequalities.

The success in healthcare outcome is influenced by the prior economic, social, political and infrastructural positions of a country or a region.[67] The expansion of hospitals in Ethiopia are believed to have created an opportunity for people to use hospital services.[83] However, the inequality in OPD visit per capita in our study revealed insignificantly reduction and yet the net between-region inequality (75.1%) remained very high. The inequality was high in two of the pastoral/semi-pastoral regions, Afar and Gambella. People living in remote areas, those who are poor, and of ethnic minorities were found have a low hospital services use.[8,77] The inequality in OPD visit in the Ethiopian context may be explained by the low access of the hospital services to the majority of rural residents, shortage of qualified providers, weak referral linkage of the primary healthcare units with hospitals and/or other individual factors such as low awareness on benefits hospital services and limited financial capacity of people. Our finding indicated a proportional reduction in the inequality of fully immunised children (63.8%) with the reduction the reduction in the inequality in the distribution of the health centres (60.3%). Nevertheless, the inequality in the U5MR increased significantly. Previous study in Ethiopia also reported an increasing tendency in socioeconomic inequality in neonatal and under-five child mortality rates.[27] Generally, the small degrees of inequality in the U5MR and IMR among the regions identified in our study can be very difficult to reduce or eliminate because of the possible occurrence of some unavoidable differences among the individuals such as biological factors.[86]

Strengths and limitations of this study

This study provided a comprehensive understanding about the nature and extent of inequalities in selected healthcare resources and outcomes in Ethiopian. The application of the different econometric techniques to characterise the inequalities helped us to show the clear picture of the inequalities in the decentralised health system. The use of data from the annually published

HHRIs of Ethiopia, CSA of Ethiopia, and the EHDS could have contributed to the reliability and credibility of the findings. Nonetheless, our analysis was based on aggregate level secondary data that emphasised the supply perspective of the health system. We also acknowledge that the decomposition of inequality change at two points in time cannot provides information about the whole story of the inequality dynamics overtime.

Implications of this study

The success of a healthcare system of Ethiopia and the SDGs for health as a whole require a continuous and coordinated effort to reduce inequalities in people's access to healthcare. This study highlighted a high degree of inequality and an overall shortage of the healthcare resources that were reflected by elasticity values less than one. The findings also indicated a relatively higher GHE share of the healthcare infrastructure that that shows a greater emphasis on the expansion of health facilities than meeting the healthcare workforce standards of the facilities. This situation calls for a more coordinated effort of the regional and central governments to meet the healthcare needs of all people in all the regions, especially those living in the pastoral and semi-pastoral areas. The healthcare resources gap identified in this study imply the need for:

- Implementing healthcare standards and certifying the health facilities upon the fulfilment of predetermined minimum healthcare workforce and other material requirements standards, and strengthening mechanisms for monitoring inequality changes in access to basic healthcare in all the regions.
- Building institutional capacity of the regionals to closely track and address inequalities within each region.
- Introducing mechanisms to raise sufficient health budget without increasing the burden of cost on the poor citizens.

Conclusion

This study identified high inequalities in selected healthcare resources and outcomes in Ethiopia. The net between-region inequalities for almost all the indicators analysed remained very high. The small GHE coupled with high inequality makes the situation more challenging because all the other human and material resources are dependent on the limited GHE. Similar to most member states, Ethiopia has committed to achieve SDGs by 2030. Unless Ethiopia significantly scales up its efforts to increase the GHE per capita and implements inequality reduction mechanisms, the proportional progress of achievement across the regions may become unachievable. Further investigation on context-specific barriers to more equitable access in healthcare and their root causes is of paramount importance to contribute to the inequality reduction in healthcare in Ethiopia.

Authors' contributions

AW contributed in developing the concept, analysing the data and interpreting the findings and in the write-up of the manuscript. **AT** contributed from the beginning in the development of the concept, in shaping the entire work and in intellectual development and continuous review of the manuscript. Besides, he is a guarantor. **AAS** participated in developing and refining the methodology and revising the manuscript. **AO** participated in developing the methodology and interpretation of the findings.

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Figure legends

Fig. 1: Regions in Ethiopia, proportion shares and selected indicators for the year 2015 (Source: CSA Ethiopia, 2015, and EDHS 2016).

Fig. 2: Regional inequalities in selected healthcare resources distributions in Ethiopia from the year 2000 to 2015. Note: This figure indicates the extent of Gini indices for the Nurses plus midwives, all physicians, pharmacy personnel, health centres, hospitals and hospital beds by region. The share of each resource was classified based on the bottom 50%, middle 40% and top 10% of the populations of each region.

Region	Population share (%)	Population by residence		Total Fertility rate	Skilled delivery (%)	IMR/ 1000 LBs	U5MR/ 1000 LBs
		Rural (%)	Urban (%)				
Tigray (TG)	5.62	75.00	25.00	4.7	59.3	43	59
Afar (AF)	1.92	82.12	17.88	5.5	16.4	81	125
Amhara (AM)	22.68	83.79	16.21	3.7	27.7	67	85
Oromia (OR)	37.45	85.52	14.48	5.4	19.7	60	79
Somali (SO)	6.06	85.55	14.45	7.2	20.0	67	94
Ben.-Gumuz (BG)	1.12	79.90	20.10	4.4	28.6	62	98
SNNP/SN	20.32	84.37	15.63	4.4	28.6	65	88
Gambella (GA)	0.45	67.73	32.27	3.5	46.9	56	88
Harari (HA)	0.26	44.40	55.60	4.1	51.2	57	72
Addis Ababa (AA)	3.64	-	100	1.8	96.8	28	39
Dire-Dawa (DD)	0.49	37.05	62.95	3.1	56.7	67	93
National total	100	80.64	19.36	4.6	27.7	48	67

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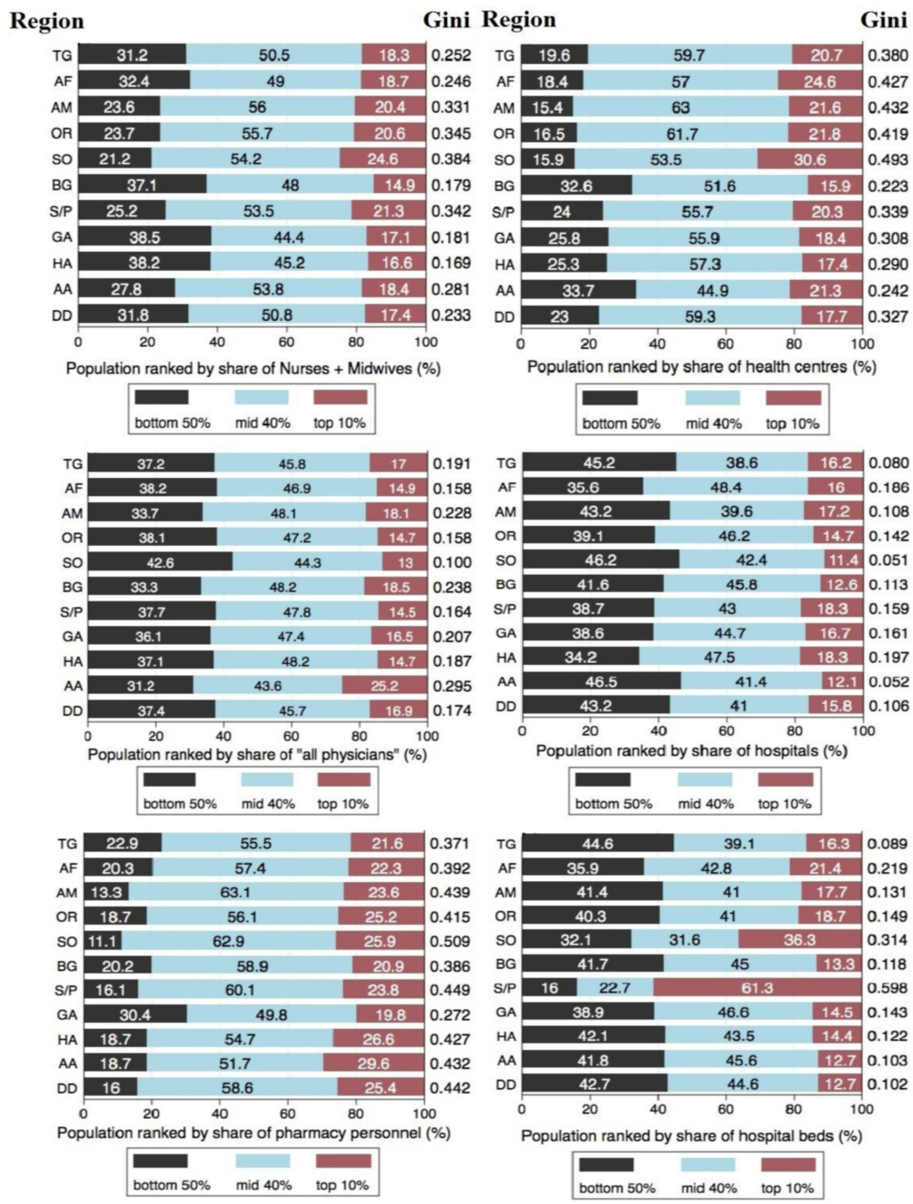

178x222mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4 - 5
Objectives	3	State specific objectives, including any prespecified hypotheses	1,5
Methods			
Study design	4	Present key elements of study design early in the paper	1,5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	NA
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	NA
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-14
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-14
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	18-19
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Inequalities in healthcare resources and outcomes threatening sustainable health development in Ethiopia: Panel data analysis

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Inequalities in healthcare resources and outcomes threatening sustainable health development in Ethiopia: Panel data analysis

Abraha Woldemichael[1,2]; Amirhossein Takian[3,4*]; Ali Akbari Sari[5]; Alireza Olyaeemanesh[4,6]

About the Authors
Abraha Woldemichael, MSc, PhD candidate[1,2]
[1]Department of Health Management and Economics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
[2]School of Public Health, College of Health Sciences, Mekelle University, Mekelle, Ethiopia
Email: abrahaw2010@gmail.com
Phone: +989303579700

Amirhossein Takian, MD, PhD, FHEA[1,3,4*]
[3]Department of Global Health and Public Policy, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
[4]Health Equity Research Centre (HERC), Tehran University of Medical Sciences, Tehran, Iran
Email: takian@tums.ac.ir
Phone: +989121041412
* Corresponding Author

Ali Akbari Sari, MD, PhD[1]
[1]Department of Health Management and Economics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
Email: akbarisari@tums.ac.ir
Phone: +989127251294

Alireza Olyaeemanesh, MD, PhD[4,5]
[4]Health Equity Research Centre (HERC), Tehran University of Medical Sciences, Tehran, Iran
[5]National Institute for Health Research, Tehran, Iran
Email: arolyaee@gmail.com
Phone: +989124117610

Abstract:

Objective: To measure inequalities in the distributions of selected healthcare resources and outcomes in Ethiopia from 2000 to 2015.

Design: A panel data analysis was performed to measure inequalities in distribution of healthcare workforce, infrastructure, outcomes, and finance, using secondary data.

Setting: The study was conducted across eleven regions in Ethiopia.

Participants: Regional population and selected healthcare workforce.

Outcomes measured: Aggregate Theil and Gini indices, changes in inequalities, and elasticity of healthcare resources.

Results: Despite marked inequalities reductions over sixteen years period, the Theil and Gini indices for the healthcare resources distributions remained high. Among the healthcare workforce distributions, the Gini index (GI) was lowest for nurses plus midwives [GI = 0.428, 95%CI: 0.393 to 0.463] and highest for specialist doctors (SPDs) [GI = 0.704, 95%CI: 0.652 to 0.756]. Inter-region inequality was the highest for SPDs (95.0%) and the lowest for health officers (53.8%). The GIs for hospital beds, hospitals and health centres (HCs) were 0.592 [95%CI: 0.563 to 0.621], 0.460 [95%CI: 0.404 to 0.517] and 0.409 [95%CI: 0.380 to 0.439], respectively. The interaction term was highest for HCs distributions (47.7%). Outpatient department visit per capita [GI = 0.349, 95%CI: 0.321 to 0.377] and fully immunised children [GI = 0.307, 95%CI: 0.269 to 0.345] showed inequalities; inequality in under-five mortality rate increased overtime (p = 0.048). Overall GI for GHE was 0.596 [95%CI: 0.544 to 0.648], and the estimated relative GHE share of the healthcare workforce and infrastructure distributions were 46.5% and 53.5%, respectively. The marginal changes in the healthcare resources distributions were towards the advantaged populations.

Conclusion: This study revealed high inequalities in healthcare resources in favour of the advantaged populations which can hinder equal access to healthcare and the achievements of healthcare outcomes. The government should strengthen monitoring mechanisms to address inequalities based on the national healthcare standards.

Keywords: Ethiopia, Gini index, Healthcare outcomes, Healthcare resources, Inequality, Inequality decomposition.

Strengths and limitations of this study

- This study attempted to provide a comprehensive picture of the extent of healthcare resources and outcomes inequalities in relation to GHE within an under-resourced country.
- The application of different inequality measures and Gini inequality decomposition models helped characterise the inequalities in healthcare resources and outcomes in a decentralised health system.
- The estimated Shapley value of the total GHE share of the selected explanatory variables indicated the priority resources, while the multidimensional Gini inequality decomposition provided the relative inequalities, the marginal changes and the elasticity values of the distributions.
- The computed overall Gini values for the distributions analysed are biased downwards around 10%.
- The analysis emphasised only the supply perspective of the health system.

Introduction

The concept of health has both moral and right elements. The central objective of many health systems is to ensure health equity among populations. Health equity may be viewed as the absence of systematic differences in health among populations regardless of their social, economic, geographical, power and prestige status.[1–3] The guiding principle within this concept is health equality[4] that may be achieved by making healthcare accessible and by addressing any socially unacceptable inequalities within healthcare, which are amenable to policy decisions.[4–6] Thus, the principle of health equality begins with creating equal opportunities for people to access needed healthcare resources, [2,7] regardless of their personal characteristics and ability to pay.[8,9]

The distinction between inequity and inequality can be blurred[10,11] because both concepts refer to unjust and socially unacceptable differences. The unfair inequities due to avoidable causes are specific forms of inequalities.[12] Nevertheless, the two concepts are not synonymous. Inequality is viewed as the quantitative description of avoidable unfair differences without value judgements that do not belong to the legitimate occurrences from individual responsibility.[13,14] In the human rights field, the concept is used in a much broader sense to describe differences among individuals, of which some could be unavoidable, at least with current knowledge and approaches.[15] Generally, the concept of inequality is a dynamic, open to different interpretations, and is highly linked to the socioeconomic structure of people.[16] Like inequity, any measure of inequality involves normative judgements.[17] We applied Braveman's definition of inequality which refers to "*differences in the distribution of resources or outcomes among people due to conditions that can be minimised or modified by policies*". [5]

The success of equality policies in healthcare is subject to the influences of the political context[18], quality of information concerning the inequality[17,19–21] and the appropriateness of the actions targeting identified unjust inequalities. However, the government policies may favour the poor especially when the share of the private sector is minimal,[22] and the economic, political, moral, or practical aspects may be used as criteria for the allocation of resources.[13] Despite the unclear link between decentralisation and inequality, decentralised policies have been common practices to ensure social justice and address inequalities.[23,24] The local governments in decentralised systems are likely to vary in power, boundaries, capacity, socioeconomic and demographic factors, living conditions and healthcare needs of their constituencies.[20,25,26] These conditions highlight the complexity and the likely occurrence of inequalities, and the coexistence of inequalities and judgements.

Ensuring fair allocation of human and material healthcare resources to people across regions contribute to better healthcare outcomes. Healthcare inequality is one of the conditions that hinder the success of healthcare systems and has been a concern to policymakers and planners. However, little evidence is available regarding the extent of healthcare inequality in the decentralised system of Ethiopia. Our study, therefore, aims to measure inequalities in selected healthcare resources and outcomes from the year 2000 until 2015. The findings are anticipated to contribute to the better understanding of the effects of the existing health policies, provide information for action towards minimising unfair inequalities, contribute to policy decisions for strengthening the Universal Health Coverage (UHC), and eventually contribute to achieve the Sustainable Development Goals (SDGs) for health in Ethiopia and perhaps beyond.

Methods

Setting:

Ethiopia is a federal democratic country that consists of nine national regional states and two chartered cities (*hereafter regions*). According to the Central Statistical Agency (CSA) of Ethiopia, 80.6% of the total population for the year 2015 resided in rural areas. The geographic location of the regions, population proportions, and other indicators for the year 2015 are presented in Figure 1.

Study design and data source

We performed panel data analysis to measure inequalities in the distribution of selected healthcare resources and outcomes in Ethiopia. Panel data analysis allows a better understanding of the trends and extent of inequalities in healthcare systems.[27] The panel consisted of annual data for eleven regions (n = 11) from the year 2000 to 2015. The data were related to GHE, healthcare workforce, healthcare infrastructure, population, and healthcare outcomes of each region. The regional data were retrieved from the Health and Health Related Indicators (HHRIs) of Ethiopia. This bulletin has been annually published by the Policy Planning Directorate of the Federal Ministry of Health (FMoH) of Ethiopia since 1994. We also used census based annual population estimates for the regions by the Central Statistical Agency (CSA) of Ethiopia, plus the five yearly reports of the Ethiopia Health and Demographic Surveys (EDHS) of 2000 to 2016.[28–32]

Patient and public involvement

We used data from the public domains and focused on the supply perspective of the healthcare system. There was no direct patient or public involvement in the data collection and analysis. This study intends to answer the following three basic distributional inequality questions in the context of Ethiopia:

- Are healthcare resources and outcomes fairly distributed across the regions?
- How were the trends and extent of the overall inequalities in the selected distributions, and which inequality component (inter-region, within-region, interaction term Gini) dominantly explained the overall inequality of each distribution?
- Which healthcare resources had the dominant share of the GHE and what were the relative inequality changes with respect to the marginal change in the average GHE?

Variables (indicators)

The total GHE and total number of each selected health professional were considered to analyse the finance and healthcare workforce dimensions of the healthcare system. These dimensions are vital for the proper functioning of the healthcare infrastructure. The total number of each functional healthcare infrastructure (health centres, the different levels of public hospitals together, and the public hospital beds) in each region were also healthcare resources related variables. The annual hospital outpatient department (OPD) visit per capita, and the proportions of fully immunised (FIMM) children, and the EDHS five yearly reports on under-five child mortality rates (U5MR) and infant mortality rates (IMR) per 1000 live births (LB) for each region were healthcare outcomes related indicators.

The GHE is a crucial determinant of healthcare,[33,34] especially in countries like Ethiopia where the public sector is the main provider of the healthcare services. The missing data on GHE for the years 2013 and 2014 and on physicians for the year 2015 for all the regions were estimated using the annual average growth rate of each distribution. The five central hospitals in Addis Ababa (AA), which were financed and managed by the Federal Government of Ethiopia, were included in the analysis for AA region. The annual total of each distribution (variable) in a region was divided by the annual total population of that region. The ratio of each distribution was again weighted by a fixed number of people to ensure consistency of the indicators, because the regions differ in population size. The summary of the indicators used in the analysis is presented below.

Dimension	Indicator
Finance:	• Per capita GHE per annum
Healthcare workforce:	• General medical practitioners (GPs) per 10,000 population [a] • Specialist doctors (SPDs) per 10,000 population [b] • All physicians (APHYs) per 10,000 population [*] • Health officers (HOs) per 10,000 population [c] • Nurses and midwives (NMWs) per 10,000 population [d] • Skilled health professionals (SKHPs) per 10,000 population [**] • Pharmacy personnel (PHARP) per 10,000 population • Medical laboratory personnel (MLABP) per 10,000 population • Environmental health personnel (ENV'THP) per 10,000 population
Healthcare infrastructure:	• Health centre (HC) per 25,000 population • Public hospital (PHP) per 100,000 population • Hospital beds (HPBs) per 10,000 population
Healthcare outcome:	• Hospital outpatient department (OPD) visit per capita • Fully immunized children (FIMM) (%) • U5MR per 1000 live births • IMR per 1000 live births

[*] = a + b [**] = a + b + c + d

Analysis and interpretation of inequality

We applied various methods to measure and decompose the inequalities. The Theil L (θ_L) and Theil T (θ_T) indices were calculated to quantify the overall inequality of the distributions over the sixteen years time period. These measures were applied to highlight different aspects of the same distribution with respect to the annual population size of the region. The θ_L (mean logarithmic deviation) is more sensitive to changes at the lower tail of a distribution, whilst θ_T is more sensitive to changes at the upper tail.[35,36] The θ_L and θ_T can be calculated using the following mathematical expressions:[37–39]

$$\theta_{L\ \alpha=0} = \frac{1}{n}\sum_{i=1}^{n} \log\frac{Y_i}{P_i} \quad \text{and} \quad \theta_{T\ \alpha=1} = \frac{1}{n}\sum_{i=1}^{n} P_i \log\frac{P_i}{Y_i}$$

Where n represents the number of regions, P_i is the population proportion of the i^{th} region, and Y_i is the proportion of a given distribution of the i^{th} region

Despite the perfect decomposition of the Theil index into between and within-region inequality components, this technique hampers the re-ranking effect on the overall inequality of a distribution. Besides, the assumption of symmetric distribution with equal variance[40] was easily violated in our case because the regions are heterogenous and more likely to have differences in the distributions.

Furthermore, we calculated the Gini index (GI) which is one of the most commonly used measures of distributional inequalities in healthcare with respect to populations.[41–44] The GI is sensitive to differences in distributions about the middle,[45] insensitive to outliers, and has a neat relationship with the Lorenz curve (LC).[46] Thus, the GI can be algebraically described as twice the area between the Lorenz curve (LC) and the 45-degree line of equality[38] and can be calculated using the following mathematical equation:[47]

$$\mathrm{GI} = 2 * \sum_{i=1}^{n} Y_i * P_i * R_i - \mu$$

where μ is the mean value of the overall distribution, n is the number of regions, Y_i, the value of a distribution in the i^{th} region, P_i is a region's population share, and R_i is the relative rank of the i^{th} region.

Despite the claim that the GI allows direct comparison of inequalities between units with different population sizes,[48] the small number of regions (N = 11), the wide difference in population size among the regions, and the direct association between population size and GI may lead to biased results. That is, the comparison of Gini inequalities among the regions and the inequality changes over time can lead to bias. Therefore, we considered the simple first-order bias correction term due to a small sample proposed by Deltas, which is expressed as follows:[49]

$$\mathrm{GI_s}^{\mathrm{adj}} = \frac{n}{n-1} * \mathrm{GI}$$

where GI_s^{adj} represents the adjusted GI for small sample and n is the number of regions. Accordingly, the GIs for the regions in our study would be underestimated by about 10%. The values of the GI range from zero (absolute equality) to one (absolute inequality).[50] The extent of the Gini inequality was judged based on the five scale values categorised as absolute equality [GI < 0.2], high equality [GI = 0.2 to 0.3], inequality [GI = 0.3 to 0.4], high inequality [GI = 0.4 to 0.6] and absolute inequality [GI > 0.6].[51] A distribution with Gini value of above 0.5 can also be considered polarised.[39] This scale was used only to create simplicity of interpretation because the extent of inequality is context specific and can be judged differently.

We further applied different Gini decomposition techniques. First, the Pyatt's[52] overall Gini decomposition technique was applied to quantify the extent of the net between-region Gini ($\mathbf{G_B}$), within-region Gini ($\mathbf{G_W}$), and the interaction pseudo-Gini ($\mathbf{G_I}$) inequality components of each distribution. The sum of these components provides the overall Gini of a distribution. This modelling approach utilizes the values of observations greater than zero. The interaction term (trans-variation, an overlap, or crossover term) is a re-ranking effect that occurs when the highest distribution in one region overlaps with the lowest distribution of the same variable in another region.[52–55] This method avoids the ambiguity that might arise from the interaction term in the Theil's index of inequality decomposition[52,56] and is more appealing to devise appropriate measures for reducing inequalities.[54]

Second, we calculated the extent of the overall inequality change between the baseline and end of study period using the Jenkins and Van Kerms'[57] decomposition of inequality changes at two points in time. Third, the Shapley post-estimation statistics was done after running the logarithm of the overall GHE (logGHE) per capita regression model on the explanatory variables (healthcare resources) to estimate their relative share of the overall GHE per capita.[58] This method uses the R-squared value of the regression model to precisely quantify the estimates by handling the problem that could arise from the residual. The estimates additively yield the overall GHE and point those variables that require explanations.[59–61] Finally, we applied the multi-dimensional decomposition of the overall GHE inequality (G_{GHE}) by the explanatory variables using the Lerman and Yitzhaki[62] method of decomposition as follows:

$$\mathbf{G_{GHE}} = \sum_{k=i}^{K} R_k * G_k * S_k$$

where K is a healthcare resource variable, which ranges from k = 0, ……K, R_k is the Gini correlation of the ranked explanatory variable with the overall GHE inequality, G_k is the Gini of the explanatory variable and S_k is the GHE share of the explanatory variable.

This technique incorporates the concept of concentration index and was used to quantify the relative marginal change, the relative GHE inequality, and the Gini elasticity of the explanatory variables with respect to the marginal change in the mean GHE and populations of the regions overtime. The relative GHE inequalities and the elasticity values of the explanatory variables were calculated manually. These measures enabled us to explain the Gini of inequalities.[63,64] We used the bootstrap and Jackknife techniques as appropriate to determine the 95% confidence interval (CI) for the indices.[65,66] All analyses were performed using Stata Statistical Software Release 14. College Station, TX: StataCorp LP. The interpretations and discussions of the findings were based on the Gini values.

Results

The Theil and Gini indices consistently revealed high overall inequalities in the GHE per capita, healthcare workforce, healthcare infrastructure and in some of the healthcare outcome indicators from the year 2000 to 2015 in Ethiopia. The aggregate inequality values of at least two of the three indices of all the indicators except for the SPDs and OPD visit per capita had intersection points in common. Despite considerable inequality reductions between the baseline and end of the study period, the GIs of many of the indicators remained strongly correlated with the overall GHE per capita inequality. The marginal increase in the mean GHE per capita resulted in a relative marginal increase in the distributions in favour of the advantaged populations of the regions. The elasticity value of less than one for all the indicators suggests the shortages. The net between-region inequality dominantly explained the overall inequality of each distribution, and the interaction term was greater than zero.

Inequality in GHE

The average overall GI for the GHE per capita was 0.596, 95%CI: 0.544 to 0.648, and marked reduction in the inequality was observed during 2006 (Fig. 2a). The overall GI for the regions ranged from 0.317, 95%CI: 0.252 to 0.381 for HA to 0.624, 95%CI: 0.526 to 0.722 for SNNP. The net inter-region inequality and the interaction term accounted for 54.4% and 37.9% of the overall GHE per capita inequality, respectively (Table 1).

Inequality in healthcare workforce

The overall GI ranged from 0.428, 95%CI: 0.393 to 0.463 for NMWs to 0.682, 95%CI: 0.646 to 0.718 for the SPDs (Table 1). Including zero values in the analysis of the time-series observations, the GI for the SPDs was 0.704, 95%CI: 0.652 to 0.756. The net inter-region inequality ranged from 53.8% for the HOs to 95% for the SPDs, and the interaction term was the lowest for the SPDs (1.6%) and the highest for the HOs (38.7%). Over the sixteen year time period, AM [GI = 0.387, 95%CI: 0.281 to 0.493] and OR [GI = 0.319, 95%CI: 0.193 to 0.444] among the agrarian regions and BG [GI = 0.368, 95%CI: 0.248 to 0.487], GA [GI = 0.356, 95%CI: 0.233 to 0.478], and AF [GI = 0.323, 95%CI: 0.223 to 0.424] among the pastoralist/semi-pastoralist regions showed inequality in the SPDs. The inequality in the distribution of the HOs was common to all regions, while SO [GI = 0.638; 95%CI: 0.435 to 0.841] and AA [GI = 0.633, 95%CI: 0.494 to 0.771] were the regions with absolute inequality. There were inequalities in NMWs, and SKHPs in SO and in all the agrarian regions except in TG. The PHARP in GA, and MLABP in BG and HA regions were fairly equally distributed. GA and all the urban/urban dominated regions had inequality in the distribution of the EVT'THP. Including zero values in the analysis, the overall GI for PHARP and EVT'THP were 0.541, 95%CI: 0.492 to 0.590, and 0.467, 95%CI: 0.402 to 0.531, respectively. The magnitude and trend of the overall inequalities in the distributions of the GHE and the healthcare workforce at national level is indicated in Figures 2 a and b.

Table 1: National level Theil and Gini indices for GHE per capita and healthcare workforce and Gini index decomposition into its components and by region at 95% confidence interval for the indices from 2000 to 2015

Measure/ Region	GHE	GP	SPDs	APHYs	HO	NMWs	SKHPs	PHARP	MLABP	ENV'THP
Overall Index										
θ_L	0.707 [0.566 to 0.848]	0.643 [0.524 to 0.763]	1.066 [0.951 to 1.181]	0.711 [0.619 to 0.803]	0.708 [0.604 to 0.812]	0.345 [0.289 to 0.402]	0.360 [0.306 to 0.414]	0.590 [0.454 to 0.726]	0.440 [0.380 to 0.501]	0.377 [0.282 to 0.471]
GI	0.596 [0.544 to 0.648]	0.591 [0.545 to 0.638]	0.682 [0.646 to 0.718]	0.612 [0.578 to 0.646]	0.577 [0.544 to 0.610]	0.428 [0.393 to 0.463]	0.437 [0.402 to 0.473]	0.539 [0.484 to 0.593]	0.491 [0.457 to 0.524]	0.457 [0.399 to 0.515]
θ_T	0.645 [0.511 to 0.779]	0.653 [0.517 to 0.789]	0.864 [0.740 to 0.988]	0.682 [0.578 to 0.786]	0.572 [0.499 to 0.646]	0.299 [0.247 to 0.351]	0.313 [0.261 to 0.366]	0.517 [0.397 to 0.636]	0.414 [0.351 to 0.476]	0.388 [0.256 to 0.521]
GI decom. (%)										
G_B	0.324 (54.4)	0.540 (91.3)	0.648 (95.0)	0.571 (93.3)	0.310 (53.8)	0.348 (81.4)	0.364 (83.2)	0.372 (68.1)	0.375 (76.5)	0.336 (73.5)
G_I	0.226 (37.9)	0.028 (4.6)	0.011 (1.6)	0.022 (3.6)	0.223 (38.7)	0.059 (13.7)	0.053 (12.1)	0.129 (24.9)	0.087 (17.7)	0.091 (19.9)
G_W	0.046 (7.7)	0.024 (4.1)	0.023 (3.4)	0.020 (3.2)	0.043 (7.5)	0.021 (4.9)	0.021 (4.7)	0.037 (7.0)	0.029 (5.8)	0.030 (6.6)
Overall GI	**0.596 (100)**	**0.591 (100)**	**0.682 (100)**	**0.612 (100)**	**0.577 (100)**	**0.428 (100)**	**0.437 (100)**	**0.539 (100)**	**0.491 (100)**	**0.457 (100)**
GI by Region										
Agrarian										
TG	0.406 [0.306 to 0.506]	0.215 [0.124 to 0.307]	0.192 [0 .070 to 0.315]	0.191 [0.117 to 0.264]	0.428 [0.329 to 0.527]	0.252 [0.183 to 0.322]	0.261 [0.195 to 0.327]	0.371 [0.277 to 0.464]	0.305 [0.249 to 0.361]	0.278 [0.197 to 0.360]
AM	0.590 [0.508 to 0.672]	0.206 [0.136 to 0.276]	0.387 [0.281 to 0.493]	0.228 [0.174 to 0.282]	0.492 [0.386 to 0.597]	0.331 [0.288 to 0.373]	0.337 [0.293 to 0.380]	0.439 [0.304 to 0.574]	0.385 [0.314 to 0.455]	0.161 [0.055 to 0.266]
OR	0.562 [0.473 to 0.651]	0.192 [0.097 to 0.286]	0.319 [0.193 to 0.444]	0.158 [0.099 to 0.218]	0.462 [0.358 to 0.567]	0.345 [0.292 to 0.397]	0.339 [0.294 to 0.384]	0.415 [0.326 to 0.504]	0.384 [0.287 to 0.482]	0.212 [0.174 to 0.250]
SNNP	0.624 [0.526 to 0.722]	0.183 [0.134 to 0.232]	0.269 [0.207 to 0.330]	0.164 [0.107 to 0.221]	0.496 [0.406 to 0.585]	0.342 [0.276 to 0.408]	0.340 [0.275 to 0.405]	0.449 [0.329 to 0.570]	0.323 [0.257 to 0.388]	0.165 [0.084 to 0.246]
Pastoral/Semi-pastoral										
SO	0.555 [0.464 to 0.647]	0.117 [0.073 to 0.162]	0.187 [0.125 to 0.249]	0.100 [0.076 to 0.125]	0.638 [0.435 to 0.841]	0.384 [0.326 to 0.442]	0.383 [0.316 to 0.450]	0.509 [0.405 to 0.614]	0.359 [0.298 to 0.421]	0.259 [0.157 to 0.361]
AF	0.436 [0.372 to 0.499]	0.171 [0.136 to 0.206]	0.323 [0.223 to 0.424]	0.158 [0.112 to 0.203]	0.407 [0.341 to 0.474]	0.246 [0.199 to 0.294]	0.242 [0.194 to 0.289]	0.392 [0.309, to 0.474]	0.363 [0.276 to 0.449]	0.192 [0.035 to 0.349]
BG	0.493 [0.429 to 0.557]	0.270 [0.184 to 0.357]	0.368 [0.248 to 0.487]	0.238 [0.148 to 0.328]	0.360 [0.293 to 0.426]	0.179 [0.132 to 0.226]	0.177 [0.137 to 0.217]	0.386 [0.301 to 0.471]	0.242 [0.184 to 0.301]	0.209 [0.106 to 0.313]
GA	0.511 [0.447 to 0.575]	0.290 [0.201 to 0.379]	0.356 [0.233 to 0.478]	0.207 [0.130 to 0.284]	0.360 [0.293 to 0.427]	0.181 [0.083 to 0.278]	0.180 [0.095 to 0.266]	0.224 [0.117 to 0.330]	0.384 [0.308 to 0.461]	0.316 [0.219 to 0.414]
Urban/urban dominated										
HA	0.317 [0.252 to 0.381]	0.281 [0.193 to 0.370]	0.197 [0.122 to 0.271]	0.187 [0.110 to 0.264]	0.483 [0.343 to 0.622]	0.169 [0.096 to 0.241]	0.157 [0.086 to 0.228]	0.427 [0.322 to 0.531]	0.276 [0.186 to 0.365]	0.485 [0.175 to 0.795]
AA	0.547 [0.447 to 0.646]	0.323 [-0.000 to 0.647]	0.300 [0.159 to 0.442]	0.295 [0.146 to 0.444]	0.633 [0.494 to 0.771]	0.281 [0.230 to 0.332]	0.275 [0.228 to 0.321]	0.432 [0.324 to 0.540]	0.344 [0.282 to 0.407]	0.436 [0.347 to 0.525]
DD	0.606 [0.509 to 0.703]	0.193 [0.139 to 0.247]	0.208 [0.138 to 0.277]	0.174 [0.107 to 0.242]	0.531 [0.422 to 0.639]	0.233 [0.191 to 0.276]	0.225 [0.188 to 0.262]	0.442 [0.345 to 0.539]	0.309 [0.236 to 0.382]	0.362 [0.183 to 0.540]

Inequality in healthcare infrastructure

The overall GI for the HCs, PHPs, and HPBs distributions, and the net between-region inequality of the same distributions accounted for 0.409, 95%CI: 0.380 to 0.439, 0.460, 95%CI: 0.404 to 0.517 and 0.592, 95%CI: 0.563 to 0.621, and 44.7%, 94.0%, and 92.1% of the overall inequality of each distribution, respectively (Table 2). The interaction term was the highest for the HCs distributions (47.7%). The overall inequality trend for the healthcare infrastructure is illustrated in Figure 2 c. BG [GI = 0.223, 95%CI: 0.168 to 0.278], HA [GI = 0.290, 95%CI: 0.244 to 0.336] and AA [GI: = 0.242, 95%CI: 0.150 to 0.335] regions had equally distributed HCs. All the regions had GIs for the PHPs and HPBs distributions less than 0.3 except for the GI for HPBs in SO [GI = 0.314, 95%CI: -0.120 to 0.748] and in SNNP [GI = 0.598, 95%CI: [-0.185 to 1.380] regions, which were insignificantly high. The regional disparities in the distributions of selected healthcare resources is graphically illustrated in Figure 3. For example, the bottom 50%, middle 40% and the top 10% of the populations in TG had access to 31.2%, 50.5% and 18.3% of the total NMWs in the region, respectively.

Inequality in healthcare outcomes

The overall GIs for hospital OPD visit per capita [GI = 0.349, 95%CI: 0.321 to 0.377] and FIMM children [GI = 0.307, 95CI: 0.269 to 0.345] revealed inequalities. The net between-region inequality of the same indicators accounted for 75.1% and 59.0% of the overall inequality, respectively (Table 2). We observed a continuous reduction in the overall inequality in the FIMM children throughout the 16-year time period (Fig. 2c). The GIs for the OPD visit per capita in AF [GI = 0.341, 95%CI: 0.249 to 0.432] and GA [GI = 0.427, 95%CI: 0.303 to 0.550], and for the FIMM children in SO (GI = 0.524, 95%CI: 0.384 to 0.665], AF [GI = 0.393, 95%CI: 0.219 to 0.566] and BG [GI = 0.311, 95%CI: 0.217 to 0.405] regions were higher than the GIs in the other regions. The net between-region inequality of the U5MR and IMR accounted for 47.1% and 49.5% of the overall inequality of each indicator, respectively.

Table 2: National level Theil and Gini Indices for healthcare infrastructure and outcomes and Gini decomposition into its components and by region at 95% confidence interval for the indices from 2000 to 2015

Measure/Region	Healthcare infrastructure, Index [95%CI]			Healthcare outcomes, Index [95%CI]			
	HCs	PHPs	HPBs	OPD	FIMM	U5MR	IMR
Overall Index							
θ_L	0.310 [0.268 to 0.351]	0.362 [0.279 to 0.444]	0.673 [0.593 to 0.752]	0.239 [0.195 to 0.283]	0.264 [0.175 to 0.352]	0.072 [0.048 to 0.096]	0.046 [0.026 to 0.067]
GI	0.409 [0.380 to 0.439]	0.460 [0.404 to 0.517]	0.592 [0.563 to 0.621]	0.349 [0.321 to 0.377]	0.307 [0.269 to 0.345]	0.208 [0.175 to 0.241]	0.163 [0.130 to 0.196]
θ_T	0.274 [0.234 to 0.314]	0.419 [0.310 to 0.527]	0.616 [0.540 to 0.693]	0.196 [0.164 to 0.228]	0.166 [0.124 to 0.209]	0.068 [0.047 to 0.089]	0.043 [0.025 to 0.061]
Gini decomp. (%)							
G_B	0.183 (44.7)	0.433 (94.0)	0.545 (92.1)	0.262 (75.1)	0.181 (59.0)	0.098 (47.1)	0.081 (49.5)
G_I	0.195 (47.7)	0.014 (3.1)	0.034 (5.7)	0.069 (19.7)	0.105 (34.2)	0.095 (45.7)	0.068 (41.5)
G_W	0.031 (7.6)	0.013 (2.9)	0.013 (2.2)	0.018 (5.2)	0.021 (6.8)	0.015 (7.2)	0.015 (9.0)
Overall GI	**0.409 (100)**	**0.460 (100)**	**0.592 (100)**	**0.349 (100)**	**0.307 (100)**	**0.208 (100)**	**0.163 (100)**
GI by region							
Agrarian							
TG	0.380 [0.330 to 0.431]	0.080 [-0.029 to 0.190]	0.089 [-0.011 to 0.190]	0.084 [0.061 to 0.107]	0.061 [0.025 to 0.096]	0.209 [0.057 to 0.362]	0.198 [0.080 to 0.316]
AM	0.432 [0.341 to 0.524]	0.108 [-0.011 to 0.227]	0.131 [0.015 to 0.248]	0.214 [0.121 to 0.307]	0.210 [0.146 to 0.273]	0.160 [0.082 to 0.239]	0.109 [0.069 to 0.149]
OR	0.419 [0.340 to 0.498]	0.142 [0.113 to 0.172]	0.149 [0.017 to 0.281]	0.155 [0.082 to 0.228]	0.231 [0.164 to 0.298]	0.175 [0.021 to 0.329]	0.129 [0.063 to 0.195]
SNNP	0.339 [0.304 to 0.373]	0.159 [0.061 to 0.258]	0.598 [-0.185 to 1.380]	0.146 [0.090 to 0.202]	0.250 [0.150 to 0.350]	0.157 [0.052 to 0.263]	0.129 [0.058 to 0.199]
Pastoral/Semi-pastoral							
SO	0.493 [0.426 to 0.561]	0.051 [0.037 to 0.065]	0.314 [-0.120 to 0.748]	0.197 [0.113 to 0.281]	0.524 [0.384 to 0.665]	0.153 [0.015 to 0.290]	0.099 [0.051 to 0.146]
AF	0.427 [0.354 to 0.500]	0.186 [0.156 to 0.217]	0.219 [0.099 to 0.340]	0.341 [0.249 to 0.432]	0.393 [0.219 to 0.566]	0.132 [-0.073 to 0.338]	0.088 [0.048 to 0.128]
BG	0.223 [0.168 to 0.278]	0.113 [0.077 to 0.149]	0.118 [0.082 to 0.155]	0.147 [0.102 to 0.192]	0.311 [0.217 to 0.405]	0.125 [-0.004 to 0.255]	0.145 [0.038 to 0.253]
GA	0.308 [0.262 to 0.354]	0.161 [0.081 to 0.241]	0.143 [0.095 to 0.191]	0.427 [0.303 to 0.550]	0.293 [0.189 to 0.397]	0.195 [0.061 to 0.329]	0.115 [0.073 to 0.157]
Urban/urban dominated							
HA	0.290 [0.244 to 0.336]	0.197 [0.114 to 0.281]	0.122 [0.069 to 0.174]	0.223 [0.165 to 0.282]	0.133 [0.079 to 0.186]	0.199 [0.001 to 0.397]	0.132 [0.069 to 0.194]
AA	0.242 [0.150 to 0.335]	0.052 [0.023 to 0.081]	0.103 [0.078 to 0.128]	0.152 [0.070 to 0.234]	0.220 [0.133 to 0.308]	0.219 [0.074 to 0.365]	0.193 [0.091 to 0.294]
DD	0.327 [0.241 to 0.413]	0.106 [0.039 to 0.173]	0.102 [0.056 to 0.149]	0.274 [0.177 to 0.371]	0.279 [0.168 to 0.389]	0.143 [0.064 to 0.223]	0.107 [0.067 to 0.146]

The overall Gini inequality changes between the baseline and end of the study period for GHE per capita indicated a 31.2% reduction in the inequality ($p = 0.030$). The GIs of the GPs, APHYs, HOs, NMWs, SKHPs, and MLABP reduced each by more than a third ($p < 0.01$) (Table 3). The reductions in the GIs for the SPDs, PHARP and ENV'THP distributions were insignificant ($p > 0.05$). The GIs for the overall distributions of the HCs and the coverage of FIMM children reduced by 60.3% and 63.8% ($p < 0.001$), respectively. The inequalities in U5MR increased by 64.5% ($P = 0.048$).

Table 3: Overall Gini Decomposition of inequality change between the years 2000 and 2015 at 95% bootstrap confidence interval for the inequality change

Indicator	Gini Index, [95%CI]		Change (Δ)		P-value
	Year 2000	Year 2015	Δ, [95% CI]	Δ (%)	
Finance					
Per capita GHE	0.446 [0.324 to 0.567]	0.307 [0.238 to 0.376]	-0.139 [-0.265 to -0.014]	- 31.2	0.030
Healthcare workforce					
GPs	0.560 [0.323 to 0.798]	0.364 [0.219 to 0.510]	-0.196 [-0.316 to -0.076]	- 35.0	0.001
SPDs	0.679 [0.485 to 0.873]	0.637 [0.463 to 0.812]	-0.042 [-0.177 to 0.093]	- 6.2	0.543
APHYs	0.581 [0.415 to 0.746]	0.355 [0.251 to 0.460]	-0.226 [-0.366 to -0.085]	- 38.8	0.002
HOs	0.461 [0.345 to 0.577]	0.288 [0.206 to 0.370]	-0.173 [-0.292 to -0.054]	- 37.5	0.004
NMWs	0.433 [0.320 to 0.546]	0.269 [0.144 to 0.393]	-0.164 [-0.262 to -0.066]	- 37.9	0.001
SKHPs	0.448 [0.305 to 0.592]	0.277 [0.160 to 0.393]	-0.172 [-0.263 to -0.081]	- 38.3	0.002
PHARP	0.492 [0.349 to 0.636]	0.409 [0.261 to 0.556]	-0.084 [-0.215 to 0.047]	- 17.0	0.210
MLABP	0.519 [0.220 to 0.819]	0.315 [0.116 to 0.514]	-0.204 [-0.315 to -0.094]	- 39.3	<0.001
ENV'THP	0.450 [0.252 to 0.648]	0.378 [0.219 to 0.536]	- 0.072 [-0.204 to 0.060]	-16.0	0.284
Healthcare Infrastructure					
HCs	0.313 [0.156 to 0.470]	0.124 [0.021 to 0.227]	-0.189 [-0.242 to -0.136]	- 60.3	<0.001
PHPs	0.506 [0.134 to 0.879]	0.523 [0.175 to 0.870]	0.016 [-0.146 to0.179]	3.2	0.843
HPBs	0.541 [0.444 to 0.639]	0.444 [0.224 to 0.663]	-0.098 [-0.310 to 0.115]	- 18.0	0.367
Healthcare outcomes					
OPD visit	0.343 [0.242 to 0.445]	0.294 [0.160 to 0.428]	-0.050 [-0.141 to 0.042]	- 14.4	0.286
FIMM	0.408 [0.264 to 0.553]	0.148 [0.064 to 0.232]	-0.261 [-0.392 to -0.130]	- 63.8	<0.001
U5MR	0.082 [0.022 to 0.142]	0.135 [0.046 to 0.224]	0.053 [0.000 to 0.105]	64.5	0.048
IMR	0.075 [0.027 to 0.123]	0.117 [0.031 to 0.202]	0.041 [-0.015 to 0.097]	54.6	0.150

The estimated Shapley value indicated that the relative share of the healthcare workforce and healthcare infrastructure distributions were 46.5% and 53.5% of the overall GHE, respectively. The HOs (18.09%), NMWs (17.20 %), MLABP (10.65%), PHARP (9.58%) and HCs (32.32%) had higher relative shares of the GHE (Table 4). Column three of Table 5 shows the strong correlation between these variables and the overall inequality in GHE per capita. Column five and seven indicate the relative GHE inequality and elasticity values of the explanatory variables relative to a marginal change in the average GHE per capita. The elasticity values of all the variables were less than one.

Table 4: Estimated Shapley value of overall logGHE share of selected healthcare resources from 2000 to 2015 in Ethiopia.

Factor	Estimated Shapley value of GHE share of selected healthcare resources				
	Value	%		Value	%
GPs	0.0173	2.24	Group 1	**0.3594**	**46.48**
SPDs	0.0155	2.01			
HOs	0.1398	18.09			
NMWs	0.1330	17.20			
PHARM	0.0741	9.58			
MLABP	0.0823	10.65			
ENVTHP	0.0171	2.21			
HCs	0.2499	32.32	Group 2	**0.4138**	**53.52**
PHPs	0.0198	2.57			
HPBs	0.0242	3.13			
Total	**0.7731**	**100.00**		**0.7731**	**100.00**

The highest and lowest relative GHE inequality and Gini elasticity were for the HOs (0.8525 vs. 0.8513) and environmental health personnel (0.3750 vs. 0.3612), respectively. The marginal increase in the average GHE resulted in a marginal increase in the distributions of all the explanatory variables (column six) towards the privileged people among the regions (the negative sign indicated the concentration of the indicator among the advantaged populations). Ceteris paribus, a one percent increase in the GHE per capita resulted in a 0.0027 percent increase in the distribution of the GPs towards the most affluent people among the regions.

Table 5: Relative marginal effects of overall GHE inequality and elasticity of selected healthcare resources overtime from 2000 to 2015 in Ethiopia.

Explanatory Variable (K_i)	GHE Share (S_k)	Gini of Component (G_k)	Correlation with GHE (R_k)	Share of GHE Inequality (I_k) = (R_k * G_k * S_k)/G_{GHE}	Relative GHE Inequality (I_k/S_k)	Relative marginal change (I_k-S_k) %, [95% bootstrap CI]	Elasticity (η_k) = (R_k * G_k)/G_{GHE}
GPs	0.0048	**0.5913**	**0.4430**	0.0021	**0.4375**	**-0.0027** [-0.0036 to -0.0018]	**0.4395**
SPDs	0.0026	**0.7036**	**0.4032**	0.0013	**0.5000**	**-0.0014** [-0.0019 to -0.0008]	**0.4760**
HOs	0.0061	**0.5771**	**0.8792**	0.0052	**0.8525**	**-0.0009** [-0.0013 to -0.0005]	**0.8513**
NMWs	0.0674	**0.4281**	**0.7967**	0.0386	**0.5727**	**-0.0288** [-0.0340 to -0.0237]	**0.5723**
PHARM	0.0082	**0.5413**	**0.8166**	0.0061	**0.7439**	**-0.0021** [-0.0027 to -0.0015]	**0.7417**
MLABP	0.0093	**0.4909**	**0.8061**	0.0062	**0.6667**	**-0.0031** [-0.0038 to -0.0025]	**0.6640**
ENV'THP	0.0040	**0.4665**	**0.4615**	0.0015	**0.3750**	**-0.0026** [-0.0033 to -0.0018]	**0.3612**
HCs	0.0068	**0.4092**	**0.8107**	0.0038	**0.5588**	**-0.0030** [-0.0036 to -0.0024]	**0.5566**
PHPs	0.0109	**0.4605**	**0.5459**	0.0046	**0.4220**	**-0.0063** [-0.0076 to -0.0050]	**0.4218**
HPBs	0.0764	**0.5920**	**0.4889**	0.0371	**0.4856**	**-0.0393** [-0.0511 to -0.0275]	**0.4856**
Total G_{GHE}		**0.5960**					

Discussion

This study analyzed the trend and degree of inequalities in the distributions of selected healthcare resources and outcomes from 2000 to 2015 in Ethiopia. Our findings revealed a high degree of overall inequalities in most of the distributions included in our analysis. The net between-region inequality in GHE accounted for 54.4% of the average overall GHE inequality in Ethiopia. Although better economic position of a country and sufficient allocation of GHE can positively influence health system outcomes,[67] decentralisation in the under-resourced countries may lead to more interregional inequalities.[68] Nevertheless, evidence from high-income countries with decentralised governance revealed no increased interregional inequalities in health expenditure per capita.[69] The high overall GHE inequality observed in our study could be due to multiple factors including the regional differences in prioritising health, development priorities or compliance to the national health policies.[70] Like the evidence from other studies, the small allocation of GHE, the difference in the roles of the regional governments with respect to spending on health,[71] differences in economic performances of the regions, and the weak balancing mechanisms [34,72] could have contributed to the GHE inequalities shown in our findings.

The significant reduction in the GHE inequality observed in our study could be related to an increased fair allocation of the GHE due to the progressive improvement of the national GDP during the last decade.[73] Besides, the reduction in the GHE inequality might imply the increased regional governments' commitment to spending more on health,[74–76] improvements in governance [77,78] or increased commitment of the development partners to health. Nevertheless, the overall GHE inequality remained too high and sufficient enough to contribute to the regional inequalities in healthcare. The strong correlation between the overall GHE inequality and the inequalities in some of the healthcare resources may indicate the prioritisation of healthcare resources by national and regional governments, whose success depends on the rational distribution of healthcare resources.[79] Evidence from a study in South Africa showed that regions with a better capacity to use the health budget also had better opportunities to receive, allocate and spend more.[80]

A region with a high density of fairly distributed healthcare workforce is more likely to serve the healthcare needs of its people than a region with a low workforce density .[35] The high net between-region inequalities in the healthcare workforce observed in our findings might imply the shortage and the maldistribution of the limited available healthcare workforce. This was reflected by the relative marginal increase in the distributions of the healthcare resources towards the advantaged populations among the regions and the elasticity values of less than one in all the healthcare resources analysed. The elasticity values of less than for all the healthcare resource in our study, indicate that the resources are yet necessary inputs to ensure access to healthcare in the regions.[34] One study in China also reported pro-rich concentration of the health workforce,[81] while others from a developed country reported the reductions in inequalities among regions following a decentralised system.[82]

The overall inequalities in the GPs and NMWs in our study were more than three-fold [GI = 0.591 vs. GI = 0.191] and about two-fold [GI = 0.428 vs. GI = 0.267], respectively, compared with the inequalities reported from China.[83] The absolute inequality in the distribution of the SPDs across the years observed in our study coupled with the prolonged time required to train and produce the qualified GPs and SPDs, plus the turnover of the SPDs for different reasons in Ethiopia ranging from 21.4% in DD to 43.3% in the AM region[84] could make the inequality reduction more challenging. The overall inequality in APHY distribution in our study [GI = 0.612 vs. GI = 0.532] was slightly higher than that reported from a study in Fiji[48] and extremely higher than the reports from Japan[41,85] and Mongolia.[42] The relatively homogenous but small Gini values for APHYs across the regions may imply the hidden inequity phenomenon.[15]

The overall healthcare infrastructure distributions (HCs, PHPs, and HPBs) were also highly unequal when compared with the findings reported from China.[86] Nevertheless, the continuously marked reduction in the inequality of the HCs distributions and the two-thirds (60.3%) reduction in inequality indicate the efforts of the central and regional governments in improving access to primary healthcare among rural residents.[87] In contrast, the increasing tendency in the overall inequality of the PHPs may also imply an increasing inequality in the healthcare workforce, especially among the GPs and SPDs. Similarly, others reported a wide disparity in the geographic distribution of healthcare workforce, health facilities and hospital beds.[86] The high inequalities in the distributions of the healthcare infrastructure in our study might inform the regional differences in development, management, institutional capacity, priorities and strategies followed by the regions to meet the healthcare needs of the local people.

The high overall inequalities in the distributions of the healthcare resources in the context of Ethiopia, where most people live in rural areas, can challenge the uniform achievement of the health sector goals in the country. As Atkinson stated, *"a smaller cake more fairly distributed may be preferable to a bigger one with high levels of inequality"*.[16] Thus, the high inequality in the GHE across the regions might challenge the reduction of inequalities for other healthcare resource.

It is pivotal to minimize the existing inequalities among the regions, yet, the success may depend on the government's commitment to improve financing, allocation of healthcare resources, plus identification of other context-specific opportunities and barriers to reduce the inequalities.

The economic, social, political and infrastructural positions of a country or a region are fundamental to determine the success in healthcare outcomes.[67] The expansion of the PHPs in Ethiopia are believed to have created an opportunity for people to use hospital services.[87] However, the net between-region inequality in OPD visit per capita was considerably high (75.1%), and the reduction in inequality overtime was insignificant. Over a 16 years period, two of the four pastoral/semi-pastoral regions (AF and GA), had high inequality in OPD visit per capita. In Ethiopia, this inequality might be explained by low access to the hospital services among the majority of rural residents, the shortage of qualified providers, the weak referral linkage between the primary healthcare units and PHPs, plus other individual factors such as low awareness on the benefits of hospital services and financial constraints. A recent study in Ethiopia also reported the practice of daily or weekly rationing of the laboratory tests, hospital drugs prescriptions, radiological investigations, and the provision of the second best treatment,[88] all of which might contribute to the low utilisation of hospital services. People living in remote areas, those who were poor, and of ethnic minorities, were also reported to have a low hospital services use.[7,79]

Despite the marked reduction in the overall inequalities in FIMM children (63.8%) over the study period, the U5MR presented a significant inequality. Micro-level studies in Ethiopia identified the association between a hospital inaccessibility and death from a vaccine preventable disease (measles)[89] as well as the association between a HC inaccessibility and a high child mortality.[90] Others also reported an increasing tendency in socioeconomic inequality in neonatal and under-five child mortality rates.[21] Due to possible occurrence of unavoidable contextual and individual differences such as the biological factors, it would be difficult to further reduce the small degrees of overall inter-regional inequalities in the U5MR and IMR.[91]

Strengths and limitations of this study

This study provided a comprehensive understanding of the extent and trend of inequalities in selected healthcare resources and outcomes over a 16-year period in Ethiopian. The application of the different econometric models helped us describe the inequalities in the decentralised system. The comprehensive use of data from the annually published HHRIs bulletin of the FMoH of Ethiopia, the CSA of Ethiopia census-based population estimates for the regions, and the data from the five yearly EHDS reports could have contributed to the reliability and credibility of the findings. The analysis was based on a small number of regions, which could lead to a downward biased GIs for the regions with small populations. Despite we observed relatively higher inequalities for some of the indicators among the regions with smaller population size, the Gini values of the regions generated by the Pyatt's Gini decomposition technique might be underestimated. We also acknowledge that the decomposition of the inequality change in two points in time cannot provide information about the whole story of the inequality dynamics overtime. Besides, the analysis was based on the aggregate level data that emphasised the supply perspective of the health system.

Policy implications

The success of the healthcare system as a whole and the SDGs for health in the context of Ethiopia require a continuous and coordinated effort to further reduce the observed inequalities in healthcare access. This study highlighted not only the magnitude and trend of the inequalities in the distributions of the healthcare resources, but also an overall shortage of the healthcare resources. The relatively higher GHE share of the healthcare infrastructure also shows the regional and central governments' greater emphasis on the expansion of the healthcare facilities, rather than meeting the healthcare workforce standards of the facilities. This situation calls for a more coordinated effort to meet the healthcare needs of all people across all regions, especially those living in the pastoral and semi-pastoral areas. Besides, the healthcare resources gaps identified in this study imply the need for:

- Implementing the healthcare standards and certifying the health facilities upon the fulfilment of predetermined minimum healthcare workforce and material requirements, and strengthening mechanisms for monitoring inequalities in basic healthcare access in all regions.
- Building the institutional capacity of the regional health bureaus to closely track and address inequalities in distributions within each region.
- Introducing mechanisms to raise sufficient health budget without increasing the burden of cost on the poor citizens.

Conclusion

Despite the progressive reductions in the inequalities, there are still significant inequalities in the distributions of some healthcare resources and outcomes in Ethiopia. The small GHE per capita coupled with high inequalities make the situation more challenging. Similar to most member states, Ethiopia has committed to achieving SDGs by 2030. Unless Ethiopia significantly scales up its efforts to increase the GHE per capita and implement inequality reduction mechanisms, the proportional progress towards achieving the health-related SDGs across the regions may become less feasible. Further investigation of context-specific barriers to more equitable access in healthcare and their root causes is of paramount importance to contribute to the inequality reduction in healthcare in Ethiopia, and perhaps similar low-income settings.

Authors' contributions

AW contributed in developing the concept, analysing the data and interpreting the findings and in the write-up of the manuscript. **AT** contributed from the beginning in the development of the concept, in shaping the entire work and in intellectual development and continuous review of the manuscript. Besides, he is a guarantor. **AAS** participated in developing and refining the methodology and revising the manuscript. **AO** participated in developing the methodology and interpretation of the findings.

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Data sharing statement: The study was based on publicly available data. The retrieved datasets are available from the corresponding author on reasonable request.

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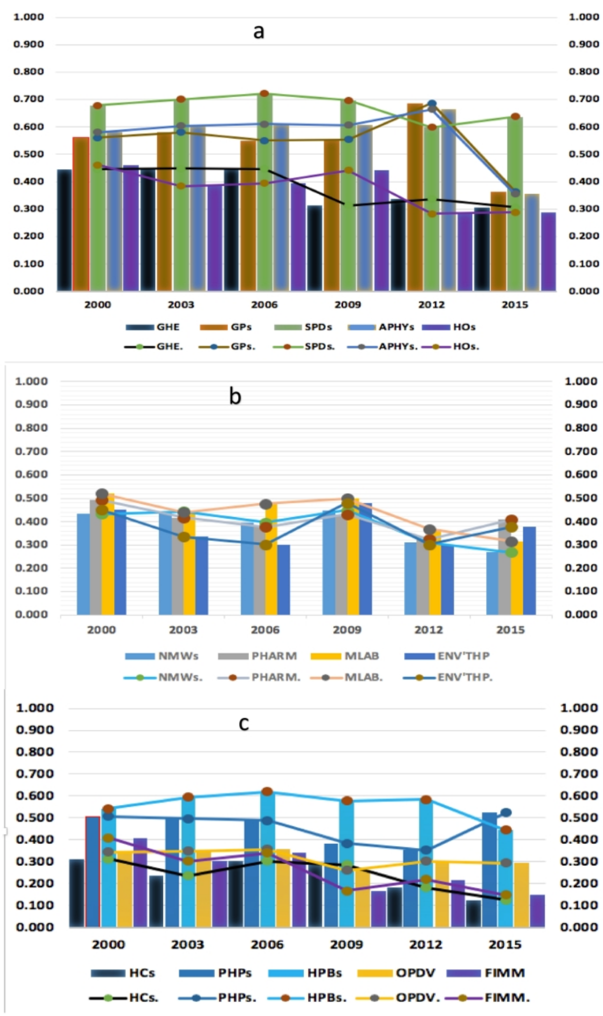
Figure legends

Fig. 1: Regions in Ethiopia, proportion shares and selected indicators for the year 2015 (Source: CSA Ethiopia, 2015, and EDHS 2016).

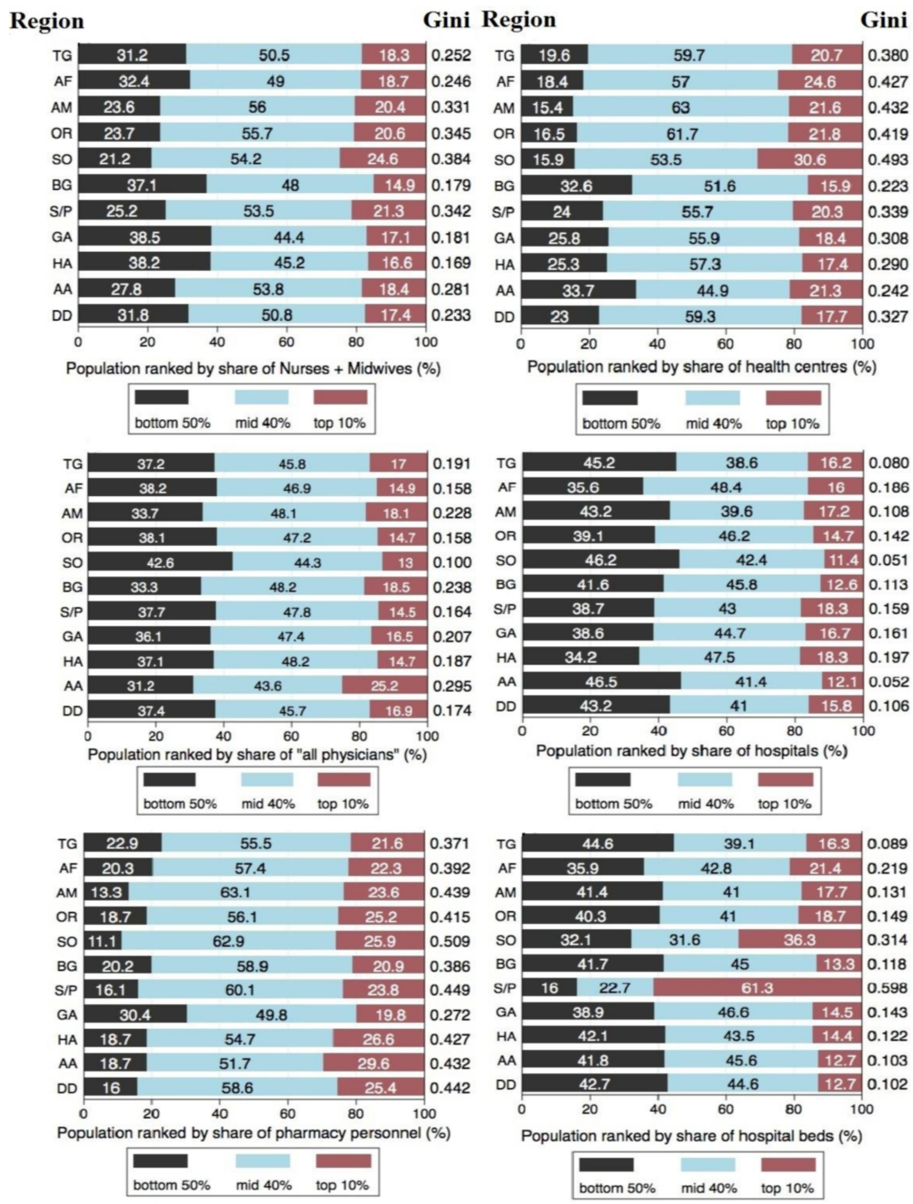
Fig. 2: Aggregate inequalities trends in selected healthcare resources distributions in Ethiopia from the year 2000 to 2015. Note: This figure presents the GIs for GHE, GPs, SPDs, HOs, NMWs, APHYs, PHARP, MLAB, HCs, PHPs, HPBs, OPD visit and FIMM children.

Fig. 3: Regional inequalities in selected healthcare resources distributions in Ethiopia from the year 2000 to 2015. Note: This figure indicates the extent of GIs for the NMWs, APHYs, PHARP, HCs, PHPs and HPBs by region. The share of each resource was classified based on the bottom 50%, middle 40% and top 10% of the population ranks of each region.

Region	Population share (%)	Population by residence		Total Fertility rate	Skilled delivery (%)	IMR/ 1000 LBs	U5MR/ 1000 LBs
		Rural (%)	Urban (%)				
Tigray (TG)	5.62	75.00	25.00	4.7	59.3	43	59
Afar (AF)	1.92	82.12	17.88	5.5	16.4	81	125
Amhara (AM)	22.68	83.79	16.21	3.7	27.7	67	85
Oromia (OR)	37.45	85.52	14.48	5.4	19.7	60	79
Somali (SO)	6.06	85.55	14.45	7.2	20.0	67	94
Ben.-Gumuz (BG)	1.12	79.90	20.10	4.4	28.6	62	98
SNNP/SN	20.32	84.37	15.63	4.4	28.6	65	88
Gambella (GA)	0.45	67.73	32.27	3.5	46.9	56	88
Harari (HA)	0.26	44.40	55.60	4.1	51.2	57	72
Addis Ababa (AA)	3.64	-	100	1.8	96.8	28	39
Dire-Dawa (DD)	0.49	37.05	62.95	3.1	56.7	67	93
National total	100	80.64	19.36	4.6	27.7	48	67



209x297mm (300 x 300 DPI)


Region
Gini
TG
AF
AM
OR
SO
BG
S/P
GA
HA
AA
DD
Population ranked by share of Nurses + Midwives (%)
Population ranked by share of health centres (%)
Population ranked by share of "all physicians" (%)
Population ranked by share of hospitals (%)
Population ranked by share of pharmacy personnel (%)
Population ranked by share of hospital beds (%)
bottom 50%
mid 40%
top 10%

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*-*REVISED*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3 - 4
Objectives	3	State specific objectives, including any prespecified hypotheses	2,4
Methods			
Study design	4	Present key elements of study design early in the paper	2,5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	NA
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-9
		(*b*) Describe any methods used to examine subgroups and interactions	6-9
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	NA
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	9-15
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-15
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11,13
Discussion			
Key results	18	Summarise key results with reference to study objectives	16-20
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.