Influence of socio-economic inequality measured by the Gini coefficient on meningitis incidence caused by *Mycobacterium tuberculosis* and *Haemophilus influenzae* in Colombia, 2008-2011

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SUMMARY

Bacterial meningitis is an important cause of infectious neurological morbidity and mortality. Its incidence has decreased with the introduction of vaccination programmes against preventable agents. However, low-income and middle-income countries with poor access to health care still have a significant burden of the disease.
Thus, the relationship between the Gini coefficient and *H. influenzae* and *M. tuberculosis* meningitis incidence in Colombia, during 2008-2011, was assessed. In this ecological study, the Gini coefficient was obtained from the Colombian Department of Statistics, incidence rates were calculated (cases/1,000,000 pop) and linear regressions were performed using the Gini coefficient, to assess the relationship between the latter and the incidence of meningitis. It was observed that when inequality increases in the Colombian departments, the incidence of meningitis also increases, with a significant association in the models ($p<0.01$) for both *M. tuberculosis* ($r^2=0.2382$; $p<0.001$) and *H. influenzae* ($r^2=0.2509$; $p<0.001$). This research suggests that high Gini coefficient values influence the incidence of *Mycobacterium tuberculosis* and *Haemophilus influenzae* meningitis, showing that social inequality is critical to disease occurrence. Early detection, supervised treatment, vaccination coverage, access to health care are efficient control strategies.

Keywords: bacterial meningitis, socioeconomic factors, healthcare disparities, social conditions, Colombia.

INTRODUCTION

Bacterial meningitis is a disease that affects the central nervous system (CNS) and can be caused by various pathogens, including *Streptococcus pneumoniae, Neisseria meningitidis, Haemophilus influenzae* and *Mycobacterium tuberculosis*. Risk of acquiring meningitis is high among those belonging to the extreme ages of life, immunosuppressed individuals, alcohol and drug addicted and pregnant women [1].
Diagnosis of meningitis may be troublesome in specific and at risk populations and adequate treatment strategies are auspicable to ameliorate the outcome [2-4]. Worldwide it has been reported the decrease in the incidence of disease after the

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massive inclusion of vaccines, as the BCG vaccine, which does not prevent infection with *M. tuberculosis*, but this reduces its hematogenic dissemination to CNS [1, 5].

Low and middle-income countries are responsible for 98% of the estimated disability-adjusted life years (DALY) because of meningitis, particularly those with limited access to health care services. However, in high-income countries, bacterial meningitis persists as one of the leading causes of death in children under 14 years [1, 6].

According to socio-economic, environmental and health factors in the epidemiology, would impact in significant variations of the meningitis incidence. For this reason, these factors are a source of academic and public attention, allowing carrying out the search of new indicators that identify the relationship between infectious diseases, social capital, poverty and income inequality. Currently, it is known that the groups with the worst socio-economic conditions not only have less access to the health services, lower quality of them and greater burden of disease, in addition, these have other conditions such as chronic diseases at younger ages [7].

Measurement of inequalities in the field of public health is important for improvement of health situation in the developing regions, including countries such as Colombia. Gini coefficient is among the tools that can be used for this purpose, in the assessment field [8]. This measures the degree of socioeconomic inequality and takes values between zero (perfect equality) and one (total inequality) identifying the distribution of resources in an established area, which partly determines access to health services since the ability to pay can be limited by income of users [9, 10]. So, health can be conditioned by economic inequalities and influence the health status of the region, favoring specific epidemiological patterns. For this reasons, the objective of this study was to assess the relationship between Gini coefficient and incidence of meningitis by *H. influenzae* and *M. tuberculosis* in departments of Colombia between 2008 and 2011.

MATERIALS AND METHODS

Colombia is a South American country constituted by 32 departments (main administrative level), with a total estimated total population of 48,747,632 for year 2016, and an average Gini coefficient of 0.51.

Study design

For this record-based, ecological study, the epidemiological data was constituted by all the meningitis confirmed cases caused by *Haemophilus influenzae* and *Mycobacterium tuberculosis* during the period between 2008-2011, reported to the national surveillance system (*Sistema Nacional de Vigilancia en Salud Pública*, SIVIGILA) of the Ministry of Health (Ministerio de Salud y Protección Social) in Colombia. Accurate data was not available before 2008. Since the investigation was retrospective and based entirely on the results of the routine investigation, informed consent was not obtained for this study. Inclusion or exclusion criteria were not used to process these data.

Data management and statistical analysis

Data were tabulated on a report form prior to be analyzed. The rates of incidence (cases/1,000,000 pop) were calculated using official reference population provided by the Colombian Department of Statistics. Simple non-linear regressions between the Gini coefficient and the incidence of bacterial meningitis caused by *H. influenzae* and *M. tuberculosis* at the departmental level in Colombia were assessed to determine the association. Statistical analyses were performed on Stata® v.11.1. Statistical significance was defined as $p<0.01$.

Available reports for *H. Influenzae* do not discriminate the individual presence of its different serotypes.

RESULTS

During the period 2008-2011, 270 cases of meningitis were caused by *H. influenzae* and 664 by *M. tuberculosis*, totaling 934 cases of bacterial meningitis for these etiological agents in Colombia.

For tuberculous meningitis, cases were diagnosed mainly in Bogota D.C. (23.8%), Valle del Cauca (19.7%) and Huila (15.5%). The highest incidence rates by department were reported in Huila (42.82 cases/1,000,000 pop) during 2011 and Quindío (29.1 cases/1,000,000 pop) in 2010.

For meningitis by *H. influenzae*, cases were diagnosed mainly in Antioquia (17.8%), Bogotá

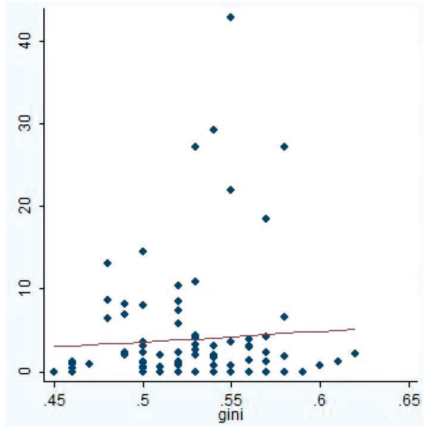
D.C. (12.9%) and Córdoba (11.9%). The highest incidence rates by department were reported in Córdoba (23.64 cases/1,000,000 pop) during 2011, Guaviare (9.83 cases/1,000,000 pop) in 2009 and Cauca (8.34 cases/1,000,000 pop) in 2010.

Twenty-five, out of thirty-two departments presented at least one case during the period of the study.

We found that with a higher inequality in the departments (as measured by the Gini coefficient), a higher incidence of meningitis was found, being significant its association in the regressions ($p<0.01$) for both, *M. tuberculosis* ($r^2=0.2382$; $p<0.001$) (Figure 1) and *H. influenzae* ($r^2=0.2509$; $p<0.001$) (Figure 2).

DISCUSSION

Incidence of meningitis has been associated with the access to health services, country's income and the index of Unsatisfied Basic Needs (UBN) [1, 6, 8]. Although the Gini coefficient and its association with the incidence of meningitis due to *H. influenzae* and *M. tuberculosis* was not previously available in scientific publications, some



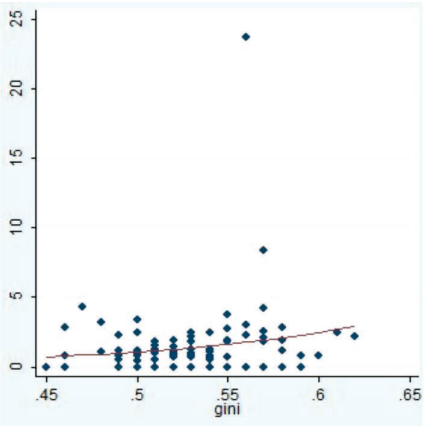
Source	SS	df	MS
Model	1505.55018	2	752.775089
Residual	4814.92617	94	51.2226188
Total	6320.47635	96	65.8382953

Number of obs = 96
F(2, 94) = 14.70
Prob > F = 0.0000
R-squared = 0.2382
Adj R-squared = 0.2220
Root MSE = 7.156998
Res. dev. = 648.2885

2-param. exp. growth curve, rate=b1*b2^gini

rate	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
b1	.7383745	2.029267	0.36	0.717	-3.290782	4.767531
b2	23.51828	120.3211	0.20	0.845	-215.382	262.4186

Figure 1 - Linear regression between the incidence of meningitis by *Mycobacterium tuberculosis* and Gini coefficient for departments in Colombia, 2008-2011.



Source	SS	df	MS
Model	214.606738	2	107.303369
Residual	640.821934	94	6.81725461
Total	855.428672	96	8.91071533

Number of obs = 96
F(2, 94) = 15.74
Prob > F = 0.0000
R-squared = 0.2509
Adj R-squared = 0.2349
Root MSE = 2.610987
Res. dev. = 454.6829

2-param. exp. growth curve, rate=b1*b2^gini

rate	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
b1	.017526	.0480494	0.36	0.716	-.0778771	.1129291
b2	3853.6	19197.05	0.20	0.841	-34262.59	41969.79

Figure 2 - Linear regression between the incidence of meningitis by *Haemophilus influenzae* and Gini coefficient by departments in Colombia, 2008-2011.

investigations have determined the relationship between that social indicator and sexually transmitted infections, especially with the Human Immunodeficiency Virus (HIV) infection [11]. However, a study that approached social determinants of tuberculosis case rates in the United States demonstrated a relationship between a Gini coefficient close to 1 and an increase in the risk of the disease [7].

A study conducted in the United Kingdom about the incidence of tuberculosis revealed that the variables associated with poverty and income inequality were important predictors for the increased incidence of this pathology. Although the Gini coefficient was a high predictor, it was not a statistically strongest predictor since in this case the social capital measured by Putnam was the most relevant [12].

It has been described that in some communities up to 58% of the population affected with tuberculosis has low income and little or no ability to pay for health services. Recent assessments of socio-economic interventions in Peru, with strategies such as economic alleviation of poverty with generation and increased revenue, managed to increase the detection of cases and success in the treatment of tuberculosis, as well as to improve the control and surveillance of the disease reduced the extra-pulmonary forms such as tuberculous meningitis cases; thus, the intervention on socio-economic factors has a direct impact on the incidence and spread of disease [13].

About the Gini coefficient and the incidence of *Haemophilus influenzae* we did not found previous published reports. However, a study published in the 1970s found that socioeconomic factors in children of white race did not influence the incidence of meningitis due to *H. influenzae* [14]. In the 1990s the rate of fatality meningitis caused by *Haemophilus influenzae* was not different in industrialized or undeveloped countries, as opposed to what was happening with access to health [15].

In a study conducted in Colombia, it was found a decrease of 40% in cases of meningitis in children less than 12 months after the introduction of the Hib vaccine in 1998. These changes are similar to those reported in other countries like United States of America (USA), El Salvador and other areas of Latin America; an example of this occurred in a city in the northeast of Brazil where the program of vaccination against Hib caused a decrease of 69% after one year of application [16, 17]. Likewise, a study in Spain showed that the incidence of tuberculous meningitis decreased during the past 15 years since the implementation of BCG vaccination [18]. In addition, a meta-analysis of 10 randomized controlled trials showed that the average protection against TB meningitis and disseminated TB was 86% and 75% in case-control studies [19]. Therefore, after the inclusion of mass vaccination coverage the epidemiological profile of the disease has changed drastically; nevertheless, strategies against TB have been insufficient for by its associated risk factors [12, 19].

The study showed that with a higher value of the Gini coefficient, a higher incidence of meningitis due to *H. influenzae* and *M. tuberculosis* is found. Although the occurrence of diseases is multifactorial, it was shown that socioeconomic inequality is associated by 25% and 23% for *H. influenzae* and *M. tuberculosis*, respectively. It is not possible to determine specifically the relationship of the different subtypes of *H. influenzae*, since the source of information does not discriminate these data.

It is expected that countries like Colombia and others with similar epidemiological and socio-economic profiles, mainly in Latin America, would use indicators that allow to further studies these associations. This should be encouraged in the field of public health to help us to determine the state of a situation or a health condition and to drive decisions in public health.

Conflict of interest. The authors have no conflicts of interest to disclose

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