

# Leukemia mortality trend in Colombia and its capital city, Bogotá: an ecological study between 1985 and 2012

## Tendência da mortalidade por leucemia na Colômbia e sua capital, Bogotá: um estudo ecológico de 1985 a 2012

Astrid Catalina Florez Buitrago<sup>1</sup> , Adalberto Luiz Miranda-Filho<sup>1</sup> , Gina Torres Rego Monteiro<sup>1</sup> , Rosalina Jorge Koifman<sup>1</sup> , Sabrina da Silva Santos<sup>1</sup>

<sup>1</sup> Fundação Oswaldo Cruz, Escola Nacional de Saúde Pública Sergio Arouca, Rio de Janeiro, Rio de Janeiro, Brasil

### ABSTRACT

**OBJECTIVE:** To analyze the leukemia mortality trend in children and adults living in Colombia and Bogotá, from 1985 to 2012. **METHODS:** This observational ecological study analyzed the mortality trend due to lymphoid, myeloid, and all types of leukemia, categorized by age, sex, and residence. Information on deaths and population data was obtained from the National Department of Statistics website. Mortality rates were used to estimate the Average Annual Percent Change (AAPC). **RESULTS:** Between 0–14 years old group, the mortality rates for leukemia fell during the studied period in Colombia (AAPC = -0.9; 95% CI -1.2, -0.6) and in Bogotá (AAPC = -2.0; 95% CI -2.6, -1.4). However, a statistically significant increase in leukemia mortality rates was observed between 60–69 years old in Colombia (AAPC = 1.1; 95% CI 0.3, 2.0) and  $\geq 70$  years old in Colombia (AAPC = 2.0; 95% CI 1.7, 2.4) and in Bogotá (AAPC = 0.9; 95% CI 0.0, 1.7). The  $\geq 70$  years old group presented the highest leukemia mortality rates in both places. **CONCLUSION:** There is a declining trend in mortality for all types of leukemia between the ages 0–14 years in Colombia, most pronounced in the capital. However, there is an increasing trend in the elderly.

**Keywords:** Leukemia; Mortality; Time Series Studies; Ecological Studies.

### RESUMO

**OBJETIVO:** Analisar a tendência da mortalidade por leucemia em crianças e adultos residentes na Colômbia e em Bogotá, entre 1985 e 2012. **MÉTODOS:** Trata-se de um estudo observacional do tipo ecológico, analisando a tendência da mortalidade por leucemia linfóide, mielóide e todos os tipos de leucemias, por idade, sexo e residência. Informações sobre mortes e dados populacionais foram obtidas no site do Departamento Administrativo Nacional de Estadística. As taxas de mortalidade foram usadas para estimar a mudança percentual anual média (Average Annual Percent Change – AAPC). **RESULTADOS:** Entre 0–14 anos de idade, as taxas de mortalidade por leucemia caíram no período estudado na Colômbia (AAPC = -0,9; IC 95% -1,2, -0,6) e em Bogotá (AAPC = -2,0; IC 95% -2,6, -1,4). No entanto, foi observado um aumento estatisticamente significativo nas taxas de mortalidade por leucemia entre 60–69 anos de idade na Colômbia (AAPC = 1,1; IC 95% 0,3, 2,0) e entre  $\geq 70$  anos de idade na Colômbia (AAPC = 2,0; IC 95% 1,7, 2,4) e em Bogotá (AAPC = 0,9; IC 95% 0,0, 1,7). A faixa etária de  $\geq 70$  anos apresentou as maiores taxas de mortalidade por leucemia nos dois locais. **CONCLUSÃO:** Há uma tendência decrescente na mortalidade para todos os tipos de leucemia entre 0–14 anos de idade na Colômbia, mais pronunciada na capital. No entanto, há uma tendência crescente em idosos.

**Palavras-chave:** Leucemia; Mortalidade; Estudos de Séries Temporais; Estudos Ecológicos.

### Correspondence / Correspondência:

Gina Torres Rego Monteiro  
Fundação Oswaldo Cruz, Escola Nacional de Saúde Pública Sergio Arouca  
Av. Leopoldo Bulhões, 1480, sala 812. Bairro: Bonsucesso. CEP: 21041-210 – Rio de Janeiro, Rio de Janeiro, Brasil  
E-mail: gtorres@ensp.fiocruz.br / ginatrm@gmail.com

## INTRODUCTION

Colombia, in 2012, presented the 15th highest cancer age-standardized mortality rate (85.0 deaths per 100,000 people) among the 20 Latin American countries. However, in relation to leukemia mortality, this country presented the sixth highest rate (4.1/100,000), similar to Uruguay (4.0/100,000), and overcoming countries like Brazil (3.5/100,000), Argentina (3.5/100,000), and Chile (3.1/100,000)<sup>1</sup>. This scenario has remained, according to the most recent estimates. In 2018, Colombia presented the 16th highest age-standardized mortality rate for cancer (79.2/100,000) and the sixth highest mortality rate for leukemia (4.1/100,000)<sup>2</sup>.

According to cancer mortality estimates from the Cancerology National Institute of Colombia, during 2007–2011, the cancer locations responsible for the highest number of cancer deaths among men were stomach, prostate, lung, colorectal and anus, and due to leukemia. In women, the main locations were breast, cervix, stomach, lung, and colorectal and anus. For children (0–14 years old), the highest number of cancer deaths were due to leukemia. There were 869 (4.2/100,000) leukemia deaths per year in men, 741 (3.3/100,000) in women, and 256 in children (2.2/100,000 boys and 1.7/100,000 girls)<sup>3</sup>.

In developed countries, the leukemia age-adjusted mortality rate trend showed a steady declining pattern since the 1970s. In the European Union, Malvezzi et al.<sup>4</sup> observed a continuing fall in mortality rates from 1970 to 2012, for both sexes (Average Annual Percent Change – AAPC = -0.7 for men and AAPC = -1.0 for women,  $p < 0.05$ ). In the USA, Chatenoud et al.<sup>5</sup> found a steady decrease in leukemia mortality since the early 1980s. However, this continuing fall was not observed in the developing countries of Latin America, which presented limited declines in Argentina, Chile, Costa Rica, Cuba, Puerto Rico, and Venezuela; and increases in Brazil and Ecuador. In Colombia, mortality rate was stable for both sexes from 1984 to 2009 (AAPC = -0.2 for men and AAPC = 0.2 for women,  $p > 0.05$ ). Moreover, even for developed countries, the mortality rates declining differ according to age groups, being more consistent at a young age<sup>6</sup>. Curado et al.<sup>7</sup>, when analyzing the leukemia mortality trend in children, adolescents, and young adults, found stability for Colombia between 1984 and 2004 for the age groups 0–14 and 15–24 years, in both sexes. However, there are no published studies on the leukemia mortality trend in Colombia and in the country's capital, Bogotá, according to age groups and leukemia type.

Therefore, the aim of this study was to analyze the leukemia mortality trend in children and adults living in Colombia and Bogotá, between 1985 and 2012, by sex, age, and leukemia type, identifying the similarities and differences between the AAPC in these two locations.

## METHODS

### STUDY POPULATION AND DESIGN

This is an observational ecological study of the leukemia mortality pattern, categorized by sex, age, and

leukemia type, in Colombia and Bogotá, between 1985 and 2012.

Deaths and population data came from the National Administrative Department of Statistics (Departamento Administrativo Nacional de Estadística – DANE) website, a government agency responsible for the consolidation and validation of vital statistics in the territory. The quality of DANE's death data was assessed by Cendales and Pardo<sup>8,9</sup> over two time periods (2002–2006 and 2007–2011) and considered to be very good. In the first period, 92.8% of all deaths and 91.5% of deaths from cancer were well certified<sup>8</sup>. In the second, the proportion of correctly certified deaths was slightly higher: 93.7% of all deaths and 92.8% of those due to cancer<sup>9</sup>. It should be noted that the main problem detected in neoplasms was the location of the primary site that does not fit for leukemias.

For this study, leukemia deaths were those whose underline cause of death had been coded as 204–208, according to the International Classification of Diseases, revision (ICD) 9, for the period between 1985 and 1997, or as codes C91–C95 of ICD-10, for the period between 1998 and 2012. For lymphocytic leukemia, it was considered the code 204 of ICD-9 or C91 of ICD-10, and for myeloid leukemia, the code 205 of ICD-9 or C92 of ICD-10.

### MORTALITY ANALYSIS

Initially, it was calculated the specific mortality rates by age group, sex, and leukemia subtype (lymphoid, myeloid, and all types of leukemia). The rates for all age groups were standardized by the direct method, using the world population proposed by Segi and modified by Doll et al.<sup>10</sup>. Then, trends for each of them were assessed using the Joinpoint regression analysis (Joinpoint Regression Program v4.6.0.0)<sup>11</sup>, available through the US National Cancer Institute Surveillance and Research Program. The independent variable was the calendar year, and the dependent variable was the natural logarithm of the age specific mortality rate, considering continuous variance throughout the period. Therefore, joint point models were used to determine the magnitude and direction of mortality rates changes through the AAPC and Annual Percent Change (APC) and respective 95% confidence intervals (CI).

## RESULTS

In Colombia, between 1985 and 2012, there was a predominance of leukemia deaths in males (19,545 deaths, Age Standardized Rate – ASR 3.93/100,000) in relation to females (16,951 deaths, ASR 3.19/100,000). In only 235 (0.64%) of these death records, age was not discriminated. In Bogotá, for this same period, age was not discriminated in 0.07% (seven) of the records and mortality rates were 7.54/100,000 men (5,265 deaths) and 5.59/100,000 women (4,625 deaths).

Both in Colombia (Table 1) and in Bogotá (Table 2), the highest leukemia mortality rates, in all periods analyzed, occurred in the population  $\geq 70$  years old and this pattern repeats itself for lymphoid and myeloid leukemia.

**Table 1** – Mortality by different types of leukemia according to sex and age groups, in Colombia, 1985 to 2012

Age group	All leukemias						Lymphoid leukemia						Myeloid leukemia					
	1985–1991	1992–1998	1999–2005	2006–2012	1985–1991	1992–1998	1999–2005	2006–2012	1985–1991	1992–1998	1999–2005	2006–2012	1985–1991	1992–1998	1999–2005	2006–2012		
	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)		
<b>Men</b>																		
0–14	2.60 (1,080)	2.26 (1,044)	2.30 (1,098)	2.16 (1,011)	1.40 (583)	1.34 (618)	1.37 (655)	1.43 (668)	0.26 (110)	0.39 (181)	0.55 (261)	0.50 (235)	0.26 (110)	0.39 (181)	0.55 (261)	0.50 (235)		
15–44	2.53 (1,337)	2.61 (1,570)	2.74 (1,819)	2.52 (1,830)	0.88 (463)	1.03 (618)	1.21 (804)	1.27 (921)	0.66 (347)	0.81 (487)	1.04 (691)	0.90 (656)	0.66 (347)	0.81 (487)	1.04 (691)	0.90 (656)		
45–59	3.99 (443)	3.88 (519)	4.05 (694)	3.70 (818)	0.96 (107)	1.07 (143)	1.12 (192)	1.24 (273)	1.46 (162)	1.60 (214)	2.06 (352)	1.80 (397)	1.46 (162)	1.60 (214)	2.06 (352)	1.80 (397)		
60–69	7.57 (371)	9.13 (502)	8.77 (562)	9.75 (770)	2.06 (101)	2.66 (146)	2.47 (158)	2.72 (215)	1.98 (97)	3.24 (178)	4.15 (266)	4.85 (383)	1.98 (97)	3.24 (178)	4.15 (266)	4.85 (383)		
≥ 70	17.87 (513)	17.94 (713)	22.37 (1,126)	26.45 (1,594)	6.37 (183)	6.11 (243)	7.49 (377)	8.07 (486)	4.67 (134)	5.86 (233)	9.24 (465)	11.17 (673)	4.67 (134)	5.86 (233)	9.24 (465)	11.17 (673)		
ASR*	3.74 (3,773)	3.76 (4,416)	4.01 (5,325)	4.05 (6,031)	1.36 (1,451)	1.45 (1,791)	1.59 (2,190)	1.69 (2,565)	0.91 (857)	1.17 (1,309)	1.59 (2,040)	1.60 (2,345)	0.91 (857)	1.17 (1,309)	1.59 (2,040)	1.60 (2,345)		
<b>Women</b>																		
0–14	2.15 (889)	2.13 (959)	2.01 (921)	1.78 (796)	1.09 (450)	1.20 (540)	1.21 (555)	1.17 (522)	0.24 (100)	0.39 (178)	0.45 (205)	0.39 (175)	0.24 (100)	0.39 (178)	0.45 (205)	0.39 (175)		
15–44	2.02 (1,098)	1.99 (1,261)	1.99 (1,377)	1.93 (1,434)	0.58 (316)	0.70 (444)	0.83 (572)	0.95 (701)	0.53 (289)	0.74 (472)	0.77 (535)	0.71 (525)	0.53 (289)	0.74 (472)	0.77 (535)	0.71 (525)		
45–59	3.51 (414)	3.53 (516)	3.79 (699)	3.56 (861)	0.81 (96)	0.99 (145)	1.14 (210)	1.22 (295)	1.26 (149)	1.37 (200)	1.84 (339)	1.72 (416)	1.26 (149)	1.37 (200)	1.84 (339)	1.72 (416)		
60–69	6.58 (344)	7.38 (451)	7.88 (561)	7.52 (661)	1.91 (100)	1.93 (118)	2.54 (181)	2.40 (211)	1.99 (104)	2.78 (170)	3.34 (238)	3.44 (302)	1.99 (104)	2.78 (170)	3.34 (238)	3.44 (302)		
≥ 70	12.07 (425)	14.26 (702)	16.79 (1,025)	19.19 (1,453)	3.75 (132)	4.57 (225)	5.40 (330)	5.70 (432)	3.41 (120)	4.63 (228)	6.73 (411)	8.09 (613)	3.41 (120)	4.63 (228)	6.73 (411)	8.09 (613)		
ASR*	3.00 (3,193)	3.13 (3,930)	3.27 (4,619)	3.21 (5,209)	0.99 (1,100)	1.14 (1,482)	1.30 (1,856)	1.35 (2,164)	0.77 (771)	1.03 (1,255)	1.25 (1,737)	1.25 (2,031)	0.77 (771)	1.03 (1,255)	1.25 (1,737)	1.25 (2,031)		
<b>Both sexes</b>																		
0–14	2.37 (1,969)	2.20 (2,003)	2.16 (2,019)	1.97 (1,807)	1.24 (1,033)	1.27 (1,158)	1.29 (1,210)	1.30 (1,190)	0.25 (210)	0.39 (359)	0.50 (466)	0.45 (410)	0.25 (210)	0.39 (359)	0.50 (466)	0.45 (410)		
15–44	2.27 (2,435)	2.30 (2,831)	2.36 (3,196)	2.22 (3,264)	0.73 (779)	0.86 (1,062)	1.02 (1,376)	1.11 (1,622)	0.59 (636)	0.78 (959)	0.90 (1,226)	0.80 (1,181)	0.59 (636)	0.78 (959)	0.90 (1,226)	0.80 (1,181)		
45–59	3.74 (857)	3.74 (1,035)	3.92 (1,393)	3.63 (1,679)	0.89 (203)	1.04 (288)	1.13 (402)	1.23 (568)	1.36 (311)	1.50 (414)	1.94 (691)	1.76 (813)	1.36 (311)	1.50 (414)	1.94 (691)	1.76 (813)		
60–69	7.06 (715)	8.27 (953)	8.30 (1,123)	8.58 (1,431)	1.99 (201)	2.29 (264)	2.51 (339)	2.55 (426)	1.99 (201)	3.02 (348)	3.73 (504)	4.11 (685)	1.99 (201)	3.02 (348)	3.73 (504)	4.11 (685)		
≥ 70	14.67 (938)	16.15 (1,415)	19.31 (2,151)	22.41 (3,047)	4.93 (315)	5.34 (468)	6.35 (707)	6.75 (918)	3.97 (254)	5.26 (461)	7.86 (876)	9.46 (1,286)	3.97 (254)	5.26 (461)	7.86 (876)	9.46 (1,286)		
ASR*	3.36 (6,966)	3.46 (8,346)	3.62 (9,944)	3.61 (11,240)	1.17 (2,548)	1.30 (3,276)	1.44 (4,046)	1.51 (4,729)	0.84 (1,628)	1.10 (2,564)	1.41 (3,777)	1.41 (4,376)	0.84 (1,628)	1.10 (2,564)	1.41 (3,777)	1.41 (4,376)		

Rate per 100,000 inhabitants; \* ASR and number of deaths for all age groups and cases with unknown age.

**Table 2** – Mortality by different types of leukemia according to sex and age groups, in the city of Bogotá, 1985 to 2012

Age group	All leukemias						Lymphoid leukemia						Myeloid leukemia					
	1985-1991	1992-1998	1999-2005	2006-2012	1985-1991	1992-1998	1999-2005	2006-2012	1985-1991	1992-1998	1999-2005	2006-2012	1985-1991	1992-1998	1999-2005	2006-2012		
Men	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)		
0-14	5.00 (281)	4.54 (290)	3.87 (256)	3.50 (229)	3.47 (195)	2.96 (189)	2.37 (157)	2.60 (170)	0.64 (36)	0.89 (57)	1.15 (76)	0.75 (49)	0.64 (36)	0.89 (57)	1.15 (76)	0.75 (49)		
15-44	5.66 (429)	5.04 (480)	4.75 (524)	3.82 (463)	2.53 (192)	2.36 (225)	2.34 (258)	2.21 (268)	1.70 (129)	2.02 (192)	2.05 (226)	1.40 (170)	1.70 (129)	2.02 (192)	2.05 (226)	1.40 (170)		
45-59	9.82 (138)	7.92 (155)	6.52 (181)	6.18 (234)	3.06 (43)	2.91 (57)	1.87 (52)	2.24 (85)	4.62 (65)	3.88 (76)	4.11 (114)	3.19 (121)	4.62 (65)	3.88 (76)	4.11 (114)	3.19 (121)		
60-69	16.70 (91)	22.81 (153)	17.48 (151)	15.68 (196)	6.61 (36)	7.75 (52)	4.98 (43)	5.20 (65)	6.79 (37)	10.29 (69)	11.00 (95)	8.16 (102)	6.79 (37)	10.29 (69)	11.00 (95)	8.16 (102)		
≥ 70	48.46 (151)	37.86 (166)	50.70 (302)	50.04 (391)	21.18 (66)	15.28 (67)	18.30 (109)	16.12 (126)	16.37 (51)	17.11 (75)	27.20 (162)	27.00 (211)	16.37 (51)	17.11 (75)	27.20 (162)	27.00 (211)		
ASR*	8.56 (1,090)	7.87 (1,248)	7.47 (1,414)	6.75 (1,513)	3.93 (532)	3.52 (592)	3.10 (620)	3.10 (714)	2.75 (318)	3.13 (472)	3.71 (673)	2.97 (653)	2.75 (318)	3.13 (472)	3.71 (673)	2.97 (653)		
Women	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)		
0-14	4.19 (241)	4.43 (281)	3.50 (222)	2.65 (166)	2.47 (142)	2.93 (186)	2.33 (148)	1.90 (119)	0.61 (35)	0.98 (62)	0.98 (62)	0.62 (39)	0.61 (35)	0.98 (62)	0.98 (62)	0.62 (39)		
15-44	3.82 (323)	3.68 (389)	3.32 (402)	2.95 (379)	1.48 (125)	1.57 (166)	1.62 (196)	1.53 (197)	1.33 (112)	1.65 (175)	1.46 (176)	1.16 (149)	1.33 (112)	1.65 (175)	1.46 (176)	1.16 (149)		
45-59	6.94 (118)	5.98 (140)	6.56 (217)	5.56 (250)	1.71 (29)	1.79 (42)	2.15 (71)	2.02 (91)	3.24 (55)	3.08 (72)	3.69 (122)	3.05 (137)	3.24 (55)	3.08 (72)	3.69 (122)	3.05 (137)		
60-69	14.47 (103)	15.34 (133)	13.39 (148)	10.78 (167)	4.64 (33)	4.50 (39)	4.07 (45)	3.61 (56)	5.34 (38)	7.84 (68)	7.69 (85)	6.07 (94)	5.34 (38)	7.84 (68)	7.69 (85)	6.07 (94)		
≥ 70	23.50 (119)	27.77 (189)	30.09 (271)	31.09 (364)	7.50 (38)	9.84 (67)	10.10 (91)	9.14 (107)	7.90 (40)	11.46 (78)	16.32 (147)	15.80 (185)	7.90 (40)	11.46 (78)	16.32 (147)	15.80 (185)		
ASR*	5.94 (904)	6.04 (1,133)	5.64 (1,262)	4.92 (1,326)	2.28 (367)	2.56 (500)	2.43 (551)	2.17 (570)	1.93 (280)	2.48 (455)	2.67 (592)	2.20 (604)	1.93 (280)	2.48 (455)	2.67 (592)	2.20 (604)		
Both sexes	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)	Rate (N)		
0-14	4.59 (522)	4.48 (571)	3.69 (478)	3.08 (395)	2.96 (337)	2.94 (375)	2.35 (305)	2.26 (289)	0.62 (71)	0.93 (119)	1.06 (138)	0.69 (88)	0.62 (71)	0.93 (119)	1.06 (138)	0.69 (88)		
15-44	4.69 (752)	4.32 (869)	4.01 (926)	3.37 (842)	1.98 (317)	1.95 (391)	1.96 (454)	1.86 (465)	1.50 (241)	1.83 (367)	1.74 (402)	1.28 (319)	1.50 (241)	1.83 (367)	1.74 (402)	1.28 (319)		
45-59	8.24 (256)	6.87 (295)	6.54 (398)	5.84 (484)	2.32 (72)	2.30 (99)	2.02 (123)	2.12 (176)	3.86 (120)	3.44 (148)	3.88 (236)	3.11 (258)	3.86 (120)	3.44 (148)	3.88 (236)	3.11 (258)		
60-69	15.44 (194)	18.60 (286)	15.18 (299)	12.97 (363)	5.49 (69)	5.92 (91)	4.47 (88)	4.32 (121)	5.97 (75)	8.91 (137)	9.14 (180)	7.00 (196)	5.97 (75)	8.91 (137)	9.14 (180)	7.00 (196)		
≥ 70	33.01 (270)	31.72 (355)	38.30 (573)	38.67 (755)	12.71 (104)	11.97 (134)	13.37 (200)	11.93 (233)	11.13 (91)	13.67 (153)	20.65 (309)	20.28 (396)	11.13 (91)	13.67 (153)	20.65 (309)	20.28 (396)		
ASR*	7.08 (1,994)	6.85 (2,381)	6.44 (2,676)	5.74 (2,839)	3.01 (899)	2.99 (1,092)	2.72 (1,171)	2.60 (1,284)	2.28 (598)	2.76 (927)	3.13 (1,265)	2.53 (1,257)	2.28 (598)	2.76 (927)	3.13 (1,265)	2.53 (1,257)		

Rate per 100,000 inhabitants; \* ASR and number of deaths for all age groups and cases with unknown age.

The mortality rates for leukemia presented a decrease pattern, during the study period, between 0–14 years old in Colombia (AAPC = -0.9) and in Bogotá (AAPC = -2.0). In Bogotá, when both sexes were considered, this decrease pattern repeats itself for other age groups, except for the  $\geq 70$  years old range,

which presented a mean increase in mortality rates by 0.9% per year, and this increase was higher in women (AAPC = 1.5). A statistically significant increase in leukemia mortality rates was also observed in Colombia in the age range of 60–69 (AAPC = 1.1),  $\geq 70$  years (AAPC = 2.0), and all ages (AAPC = 0.3) (Table 3).

**Table 3** – AAPC and respective 95% CI, according to sex, age, and leukemia types, in Colombia and Bogotá, 1985 to 2012

Age group	All leukemias		Lymphoid leukemia		Myeloid leukemia	
	AAPC	95% CI	AAPC	95% CI	AAPC	95% CI
Colombia – Men						
0–14	-0.9*	-1.3, -0.5	0.1	-0.3, 0.4	2.7*†	0.4, 5.2
15–44	0.0	-0.4, 0.4	1.8*	1.3, 2.3	1.3*†	0.0, 2.7
45–59	-0.2	-0.7, 0.2	1.2*	0.4, 2.1	1.3*	0.4, 2.1
60–69	1.1*	0.5, 1.6	2.9†	-0.2, 6.0	2.6*†	0.0, 5.3
$\geq 70$	1.9*	1.4, 2.5	1.2*	0.3, 2.2	4.3*	3.4, 5.2
ASR	0.4*	0.1, 0.6	1.0*	0.7, 1.4	2.6*†	1.6, 3.6
Colombia – Women						
0–14	-1.0*	-1.4, -0.5	0.3	-0.3, 0.8	1.8†	-0.0, 3.8
15–44	-0.2	-0.6, 0.2	2.3*	1.7, 2.8	1.4†	-0.1, 2.9
45–59	0.2	-0.3, 0.7	2.1*	0.7, 3.6	1.6*	0.8, 2.4
60–69	0.6	-0.0, 1.3	1.3*	0.1, 2.5	2.6*	1.6, 3.6
$\geq 70$	2.3*	1.8, 2.8	3.3*†	1.0, 5.7	4.3*	3.5, 5.2
ASR	0.3*	0.1, 0.5	1.5*	1.1, 1.9	2.2*†	1.2, 3.2
Colombia – Both sexes						
0–14	-0.9*	-1.2, -0.6	0.2	-0.1, 0.4	2.4*†	0.8, 3.9
15–44	-0.1	-0.4, 0.2	2.0*	1.6, 2.4	1.3*†	0.1, 2.6
45–59	-0.1	-0.4, 0.3	1.6*	0.7, 2.6	1.4*	0.7, 2.1
60–69	1.1*†	0.3, 2.0	1.2*	0.6, 1.9	3.3*†	2.1, 4.4
$\geq 70$	2.0*	1.7, 2.4	1.6*	0.9, 2.3	4.2*	3.5, 5.0
ASR	0.3*	0.1, 0.5	1.2*	0.9, 1.5	2.4*†	1.6, 3.2
Bogotá – Men						
0–14	-1.6*	-2.4, -0.8	-1.3*	-2.5, -0.2	1.8	-1.0, 4.7
15–44	-1.7*	-2.2, -1.2	-0.6	-1.3, 0.1	-0.9†	-2.4, 0.7
45–59	-2.0*	-3.0, -1.1	-1.6	-3.3, 0.2	-1.2	-2.7, 0.2
60–69	-0.5	-1.8, 0.7	-1.3	-3.0, 0.4	1.0†	-2.5, 4.6
$\geq 70$	0.4	-0.8, 1.6	-1.1	-2.5, 0.3	2.7*	1.0, 4.4
ASR	-1.1*	-1.5, -0.6	-1.1*	-1.8, -0.5	0.6	-0.3, 1.5
Bogotá – Women						
0–14	-2.4*	-3.3, -1.6	-1.6*	-2.7, -0.5	-3.5†	-14.7, 9.3
15–44	-1.4*	-2.0, -0.7	-0.1	-1.2, 1.1	-0.6	-1.9, 0.6
45–59	-0.9	-1.9, 0.2	1.2	-1.2, 3.6	-0.1	-1.6, 1.5
60–69	-1.7*	-3.0, -0.4	-1.5	-3.6, 0.7	0.2†	-2.5, 2.8
$\geq 70$	1.5*	0.5, 2.4	0.2‡	-1.3, 1.7	3.5*	2.3, 4.7
ASR	-1.0*	-1.4, -0.6	-0.4	-1.2, 0.3	0.4†	-0.9, 1.7
Bogotá – Both sexes						
0–14	-2.0*	-2.6, -1.4	-1.4*	-2.2, -0.6	-0.2†	-4.0, 3.7
15–44	-1.5*	-1.9, -1.1	-0.4	-1.0, 0.3	-0.7†	-2.2, 0.8
45–59	-1.5*	-2.1, -0.9	-0.6	-1.7, 0.5	-0.6	-1.8, 0.5
60–69	-1.0*	-2.0, -0.1	-1.3*	-2.7, -0.0	0.6†	-1.5, 2.8
$\geq 70$	0.9*	0.0, 1.7	-0.2	-1.4, 1.1	3.0*	1.8, 4.2
ASR	-1.0*	-1.4, -0.7	-0.8*	-1.3, -0.2	0.6	-0.2, 1.4

\* AAPC significantly different from zero at  $\alpha = 0.05$ . † Number of joinpoints other than zero in the final model. Leukemia in Colombia for both sexes, 60–69 years: trend 1 (1985–1992) APC = 4.0\* (95% CI 1.1, 7.0); trend 2 (1982–2012) APC = 0.2\* (95% CI -0.4, 0.7). Lymphoid leukemia in Colombia for men 60–69 years: trend 1 (1985–1989) APC = 20.5 (95% CI -1.1, 47.0); trend 2 (1989–2012) APC = 0.1 (95% CI -1.3, 1.5). Lymphoid leukemia in Colombia for women  $\geq 70$  years old: trend 1 (1985–1990) APC = 13.3\* (95% CI 0.8, 27.5); trend 2 (1990–2012) APC = 1.2 (95% CI -0.1, 2.5). APCs for myeloid leukemia are presented on table 4. ‡AAPC for the period 1986–2012. In 1985, there was no death due to lymphoid leukemia in this age group, so this year was deleted.

**Table 4** – APC and respective 95% CI for myeloid leukemia, according to sex and age, in Colombia and Bogotá, 1985 to 2012

Age group	Period	APC	95% CI
Colombia – Men			
0–14	1985–2001	6.3*	3.5, 9.2
	2001–2012	-2.2	-6.7, 2.4
15–44	1985–2002	3.4*	2.0, 4.8
	2002–2012	-2.1	-5.0, 0.9
60–69	1985–1988	-15.5	-30.2, 2.3
	1988–1996	11.8*	6.3, 17.7
	1996–2012	1.9*	0.5, 3.4
ASR	1985–2001	4.2*	3.0, 5.4
	2001–2012	0.3	-1.7, 2.4
Colombia – Women			
0–14	1985–2000	4.8*	2.4, 7.3
	2000–2012	-1.8	-4.9, 1.5
15–44	1985–1997	4.1*	1.4, 6.8
	1997–2012	-0.7	-2.5, 1.2
ASR	1985–2000	3.8*	2.6, 5.1
	2000–2012	0.2	-1.5, 1.9
Colombia – Both sexes			
0–14	1985–2000	5.8*	3.8, 7.9
	2000–2012	-1.8	-4.4, 0.9
15–44	1985–2000	3.5*	1.9, 5.1
	2000–2012	-1.3	-3.4, 0.9
60–69	1985–2000	5.4*	3.9, 6.9
	2000–2012	0.6	-1.4, 2.7
ASR	1985–2000	4.1*	3.1, 5.2
	2000–2012	0.3	-1.1, 1.8
Bogotá – Men			
15–44	1985–2000	2.4*	0.4, 4.5
	2000–2012	-4.8*	-7.5, -2.1
60–69	1985–1999	5.0	-0.1, 10.4
	1999–2012	-3.2	-8.4, 2.4
Bogotá – Women			
0–14	1985–1990	-29.5*	-44.9, -9.9
	1990–1993	79.2	-40.3, 437.4
	1993–2012	-4.9*	-7.9, -1.7
60–69	1985–2000	4.6*	1.2, 8.2
	2000–2012	-5.2*	-9.5, -0.6
ASR	1985–2000	2.8*	1.1, 4.5
	2000–2012	-2.5*	-4.7, -0.2
Bogotá – Both sexes			
0–14	1985–2003	3.7*	0.1, 7.5
	2003–2012	-7.7	-16.6, 2.1
15–44	1985–1999	2.4*	0.2, 4.6
	1999–2012	-4.0*	-6.3, -1.7
60–69	1985–2000	4.6*	1.8, 7.4
	2000–2012	-4.1*	-7.6, -0.4

\* APC significantly different from zero at  $\alpha = 0.05$ .

For lymphoid leukemia, mortality rate trends behave differently in Colombia and Bogotá. In Colombia, there was a tendency of an increase in mortality rates for all ages (AAPC = 1.0) and in different age groups, except for ages 0–14 years (AAPC = 0.2). In Bogotá, there is a decrease by -0.8% per year in mortality rate and

this behavior occurs mainly in the age groups 0–14 years (AAPC = -1.4) and 60–69 years (AAPC = -1.3) (Table 3).

For myeloid leukemia in Colombia, the AAPC shows a statistically significant increase in mortality rates across all age groups. However, this trend is only constant for



the age groups 45–59 years (AAPC = 1.4) and  $\geq 70$  years (AAPC = 4.2) (Table 3). For the other age groups, the general trend is divided into different periods, since the final model has one or two joinpoints. Thus, it can be observed that between 1985 and 2000 there was a statistically significant upward trend, but in the period of 2000 to 2012 there was stability in mortality rates (Table 4).

In Bogotá, myeloid leukemia trends were also not constant for age groups 0–14, 15–44, and 60–69 years. There was a first period of a statistically significant increase and then a period of stability for the ages 0–14 years (APC = -7.7; between 2003–2012) or a period of decrease for the ages 15–44 years (APC = -4.0; 95% CI -6.3, -1.7; between 1999–2012) and 60–69 years (APC = -4.1; 95% CI -7.6, -0.4; between 2000–2012) (Table 4). However, in Bogotá, for seniors  $\geq 70$  years old, there was an increase in myeloid leukemia mortality rates, throughout all the studied period (AAPC = 3.0; 95% CI 1.8, 4.2) (Table 3).

## DISCUSSION

Leukemia is a neoplasm characterized by imbalance in the white blood cells development, produced by genetic factors and chemical or environmental exposures<sup>12,13</sup>. The existing types of leukemia affect the age groups differently, being the findings of this article consistent with the epidemiological profile reported in the literature. For children less than 15 years old, acute lymphoblastic leukemia (ALL) represents 78% of cases, while the myeloid leukemias corresponds to 17% of cases (16% for acute myeloid leukemia and 1% for chronic myeloid leukemia). From the second decade of life onwards, the proportion of myeloid leukemias increases, with a corresponding percentage decrease in acute lymphoblastic leukemia<sup>14</sup>. Thus, the analysis of the temporal evolution of leukemia mortality rates is important not only for their magnitude but also for the complexity of the determinants.

The study of leukemia mortality profile is strongly influenced by the diagnostic capacity, the mechanisms used to consolidate information, and the population's access to specialized medical centers. Therefore, the analysis of mortality patterns measures the effort undertaken to control the disease, as well as the possible inequalities in the health care of the studied localities<sup>15,16</sup>. In Colombia, in 2012, the mortality rates for leukemia found in men (3.81/100,000) were lower than the estimate for the European Union in 2012 (4.3/100,000). However, the rate for men in Bogotá (7.04/100,000) exceeded this estimate, just as the rates for women in Colombia (3.28/100,000) and in Bogotá (4.98/100,000) were higher than the estimate for women in European Union (2.59/100,000)<sup>17</sup>, suggesting that, despite advances, there is still a need for improvements in the treatment of this neoplasm for Colombians.

According to the findings of the present study (1985–2012), in the 0–14 year age group, mortality from all leukemias revealed a statistically significant declining trend (APC = -0.9; 95% CI -1.2, -0.6), confirming

the findings of the previous study by Piñeros et al.<sup>18</sup>, in which an average annual percentage change of -1%, for the same age group, was found in an analysis of child cancer mortality in Colombia, from 1985 to 2008. The decrease evidenced in the 1990's coincide, in the political sphere, with the implementation of Law 100/1993, which regulated the General System of Social Security in Health, establishing health care for the entire Colombian population in areas of prevention, diagnosis, and treatment<sup>19</sup>. It is also important to highlight other more recent resolutions, aimed at improving child cancer survival. The Law 1388/2010 proposes to significantly reduce the death rate from cancer in children and people under 18 years old, through the guarantee of all the services required for early detection and comprehensive treatment<sup>20</sup>. In addition, the Public Health Surveillance Protocol, published in 2008, proposes a sentinel surveillance strategy to accelerate pediatric acute leukemia diagnosis and treatment initiation<sup>21</sup>. However, the decrease revealed in Colombia was lower and later in comparison to that observed, in the same age group, in developed countries like Japan (APC = -4.77, 1976–2006, for boys; and APC = -4.53, 1970–2006, for girls); United States (APC = -4.95, 1970–1984, and APC = -3.39, 1984–2005, for boys; and APC = -6.09, 1970–1980, and APC = -3.14, 1980–2005, for girls)<sup>22</sup>, and European Union countries between 1970–2006 (Denmark: APC = -4.91 and -4.16; Italy: APC = -3.67 and -4.33; United Kingdom: APC = -3.83 and -3.82; Portugal: APC = -3.67 and -2.53, for boys and girls, respectively)<sup>23</sup>. However, it could coincide with the limited reduction observed in some Latin American countries<sup>7</sup>.

The analysis, by type of leukemia, in the 0–14 years old group shows, however, a statistically significant increase for myeloid leukemia (AAPC = 2.4; 95% CI 0.8, 3.9), mainly in males (AAPC = 2.7; 95% CI 0.4, 5.2). For lymphoid leukemia, there was a stable behavior (AAPC = 0.2; 95% CI -0.1, 0.4). In Bogotá, there was a stable behavior for myeloid leukemia (AAPC -0.2, 95% CI -4.0, 3.7) and a decrease for lymphoid leukemia (AAPC = -1.4; 95% CI -2.2, -0.6). Less favorable results for myeloid leukemia compared to lymphoid leukemia were expected given the higher probability of survival in pediatric patients with lymphoid leukemia<sup>24,25,26</sup>, that varies from 50% to more than 90% in Puerto Rico, Canada, USA, and many European countries. In Colombia, the estimated probability of survival for children with acute lymphoblastic leukemia is 68.9%<sup>27</sup>. The higher rate reductions in Bogotá, compared to Colombia, make it possible to highlight the differences in access to health services and, therefore, the existence of several situations that may interfere in the flow of events related to the health service use. Among these situations, the individual's perception of personal or family health needs stand out, giving rise to the desire to obtain care, which could imply the decision to search outpatient or hospital services to obtain care<sup>28</sup>. One possible measure to minimize these differences is to consolidate the role of health professionals in the primary care level in identifying warning signs at all stages of life and knowledge about the health impact of exposure to harmful environmental and residential agents, to achieve

social mobilization in search of healthy environments and promote self-care actions in the use of household chemicals and pesticides.

The decrease pattern for lymphoid leukemia observed in the 0–14 years old group, in Bogotá, was not observed in the 15–44 (APC = -0.4; 95% CI -1.0, 0.3) and 45–59 years old groups (APC = -0.6; 95% CI -1.7, 0.5). It is known that the prognosis of lymphoid leukemia is less favorable for adolescents and adults compared to children<sup>14</sup>. However, even for these age groups some improvements have been verified in developed countries, with a better relapse control using allogenic hematopoietic stem cell transplantation, monitoring of minimal residual diseases and improving the management of treatment complications<sup>17</sup>.

The  $\geq 70$  years old group showed the highest mortality rates, in Colombia and in Bogotá, for all types and for lymphoid and myeloid leukemias. Moreover, there were increases in mortality rates for this age group, for men, women, and both sexes, in all analyses, except for women and both sexes for lymphoid leukemia in Bogotá (AAPC = -0.2; 95% CI -1.4, 1.1). The 60–69 years old group had also an increase in mortality rates for all types (AAPC = 1.1; 95% CI 0.3, 2.0) and for lymphoid (AAPC = 1.2; 95% CI 0.6, 1.9) and myeloid (AAPC = 3.3; 95% CI 2.1, 4.4) leukemias in Colombia. Studies regarding the evolution of mortality rates in the elderly are much more scarce compared to studies in other age groups, especially in children. However, it is possible to notice that, even in developed countries, older people have worse outcomes than younger people. In the United States, where there has been a decline in rates among the youngest, since 1960, there has been a notable increase in rates from 65 years old at least up to the year 2000<sup>29</sup>. Bertuccio et al.<sup>17</sup>, when comparing leukemia mortality rates for the European Union, in 1977 and 2007, showed a decrease in all age groups, except for the  $\geq 70$  years range, which showed a percentage increase of 5.58 and 1.69, for men and women, respectively.

The worst results for myeloid leukemias in the present analysis by leukemia type are in line with the scientific literature. Data from 18 high quality population-based cancer registries, available on the National Cancer Institute Surveillance, Epidemiology, and End Results (SEER) Program, for cases diagnosed from 2007 to 2013, demonstrate that survival in older adults ages (75–84 years old) is poor, particularly for acute myeloid leukemia (relative survival = 2.7%,; 95% CI 2.0–3.6)<sup>30</sup>. The structural and functional changes of the aging process lead to a decrease in the vital capacity of the organs, making the induction therapy less tolerated, with a higher risk of infection and with an increase in treatment-related mortality<sup>31,32</sup>.

The results of this study present some limitations to be highlighted. Firstly, the use of data from the DANE website brings the inherent problems of secondary data, such as inability to complete missing information or correct any data inconsistencies. In addition, the fact that, during the period considered in the study, two different ICD revisions

were used, and this divergence was addressed using a code equivalence guide<sup>33</sup>. Nevertheless, the comparison of the trend in the Colombian mortality rates in relation to those observed in the capital shows inequities in health and access conditions, representing a decrease in the effectiveness of the treatment among the Colombian population. Thus, the findings suggest the need for studies that address the distribution and hierarchization of the health network in the country, identifying the need for a greater supply of quality specialized services according to the population's health demands, respecting the balance between the demand and the provision of services. The location of specialized health entities in oncology should agree with the cancer epidemiological behavior. When financial, administrative, and security conditions do not allow the establishment of these entities, it is necessary to provide the creation and maintenance of parents and patients organizations, so that they support families and users during the treatment period, avoiding the inequality referenced in some national studies<sup>34,35</sup>.

We acknowledge that the proportion of unspecified leukemia in the death certificates can change over the time, putting uncertainty in the interpretation of the mortality rates trends. However, according to the World Health Organization, the Colombian mortality statistics were considered of medium quality, it means that completeness vary between 70% and 90%, and the proportion of deaths certified as signs, symptoms, and ill-defined conditions was between 10% and 20%<sup>36</sup>. Nevertheless, there is evidence indicating that 92.8% of the cancer deaths were correctly assigned by the mortality system<sup>9</sup>. In addition to that, according to Bravo et al.<sup>37</sup>, the proportion in unspecified leukemia in children decreased over the time, achieving less than 1% in the period 2007–2011, likely reflecting improvement in the quality of ill-defined cause of deaths in the mortality system.

On the other hand, in the last two decades, the Colombian health system has presented substantial progress in improving equity in the access to health care facilities, moving toward the complete implementation for the universal health coverage<sup>38</sup>. The public health system provides programs of primary and secondary cancer prevention, early detection, and treatment and palliative care. However, the main weakness and challenges consists to delivery effective high quality oncology care for all population<sup>39</sup>.

The findings of this article are very important to understand the behavior of leukemia in the country and in the capital. Moreover, the results can be considered as a reference point to identify the impact of the implementation of Law 1388/2010, which regulated state actions, to ensure the right to life for children with cancer throughout the country<sup>20</sup>, and to evaluate the epidemiological behavior of leukemias in other age groups.

## CONCLUSION

In the 0–14 years old group, a declining trend in mortality rates for all types of leukemia was identified



in Colombia, most pronounced in the capital. There was a decrease in historical series at ages 15 and 69 years in Bogotá, and a positive tendency for all types of leukemia deaths in age of  $\geq 70$  years old in the two studied areas. The analysis, by type of leukemia, also shows a decreasing trend for lymphoid leukemia in boys and girls from 0–14 years old in Bogotá. Therefore, the epidemiological mortality pattern is consistent with that described in the international literature. The results found in Bogotá are possibly due to the availability of specialized health centers in pediatric oncology and access to medical treatment.

#### AUTHORS' CONTRIBUTION

Conception and planning of the study: ACFB, ALM, GTRM, RJK, and SSS. Data collection, analysis and

interpretation: ACFB, RJK, and SSS. Drafting or review of the manuscript: ACFB, GTRM, and SSS. All the authors approved the final version and take public responsibility for the content of this article.

#### FINANCIAL SUPPORT

We are grateful to the Students-Postgraduate Agreement Program (PEC-PG) of the Coordination for the Improvement of Higher Education Personnel (CAPES) and of the National Council for Scientific and Technological Development (CNPq) by granting the master's scholarship grant from the first author.

#### CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.



#### REFERENCES

- 1 Ferlay J, Soerjomataram I, Dikshit R, Eser S, Mathers C, Rebelo M, et al. Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. *Int J Cancer*. 2015 Mar;136(5):E359-86.
- 2 Ferlay J, Colombet M, Soerjomataram I, Mathers C, Parkin DM, Piñeros M, et al. Estimating the global cancer incidence and mortality in 2018: GLOBOCAN sources and methods. *Int J Cancer*. 2019 Apr;144(8):1941-53.
- 3 Pardo Ramos C, Cendales Duarte R. Incidencia, mortalidad y prevalencia de cáncer en Colombia, 2007-2011. Bogotá: Instituto Nacional de Cancerología; 2015.
- 4 Malvezzi M, Carioli G, Bertuccio P, Boffetta P, Levi F, La Vecchia C, et al. European cancer mortality predictions for the year 2018 with focus on colorectal cancer. *Ann Oncol*. 2018 Apr;29(4):1016-22.
- 5 Chatenoud L, Bertuccio P, Bosetti C, Malvezzi M, Levi F, Negri E, et al. Trends in mortality from major cancers in the Americas: 1980–2010. *Ann Oncol*. 2014 Sep;25(9):1843-53.
- 6 Levi F, Lucchini F, Negri E, Barbui T, La Vecchia C. Trends in mortality from leukemia in subsequent age groups. *Leukemia*. 2000 Nov;14(11):1980-5.
- 7 Curado MP, Pontes T, Guerra-Yi ME, Camargo Cancela M. Leukemia mortality trends among children, adolescents, and young adults in Latin America. *Rev Panam Salud Publica*. 2011 Feb;29(2):96-102.
- 8 Cendales R, Pardo C. La calidad de certificación de la mortalidad en Colombia, 2002-2006. *Rev Salud Publica (Bogotá)*. 2011 Apr;13(2):229-38.
- 9 Cendales R, Pardo C. Quality of death certification in Colombia. *Colomb Med (Cali)*. 2018 Mar;49(1):121-7.
- 10 Doll R, Payne P, Waterhouse J, editors. Cancer incidence in five continents: a technical report. Berlin: Springer-Verlag Heidelberg; 1966.
- 11 National Cancer Institute (USA). Surveillance Research Program. Statistical Methodology and Applications Branch. Joinpoint Regression Program. Version 4.6.0.0 [Internet]. 2018 [cited 2019 Jan 31]. Available from: <https://surveillance.cancer.gov/joinpoint/>.
- 12 Ferreira JD, Couto AC, Alves LC, Oliveira MSP, Koifman S, Brazilian Collaborative Study Group of Infant Acute Leukemia. Exposições ambientais e leucemias na infância no Brasil: uma análise exploratória de sua associação. *Rev Bras Estud Popul*. 2012 jul-dez;29(2):477-92.
- 13 Wiemels J. Perspectives on the causes of childhood leukemia. *Chem Biol Interact*. 2012 Apr;196(3):59-67.
- 14 Ries LAG, Smith MA, Gurney JG, Linet M, Tamra T, Young JL, et al., editors. Cancer incidence and survival among children and adolescents: United States SEER Program 1975-1995 [Internet]. Bethesda (MD): U. S. National Cancer Institute; 1999 [cited 2019 Apr 16]. Available from: <https://seer.cancer.gov/archive/publications/childhood/childhood-monograph.pdf>.
- 15 Pereira MG. Epidemiologia: teoria e prática. Rio de Janeiro: Guanabara Koogan; 2008.
- 16 Travassos C, Oliveira EXG, Viacava F. Desigualdades geográficas e sociais no acesso aos serviços de saúde no Brasil: 1998 e 2003. *Cienc Saude Coletiva*. 2006 out/dez;11(4):975-86.

- 17 Bertuccio P, Bosetti C, Malvezzi M, Levi F, Chatenoud L, Negri E, et al. Trends in mortality from leukemia in Europe: an update to 2009 and a projection to 2012. *Int J Cancer*. 2013 Jan;132(2):427-36.
- 18 Piñeros M, Gamboa O, Suárez A. Mortalidad por cáncer infantil en Colombia durante 1985 a 2008. *Rev Panam Salud Publica*. 2011 jul;30(1):15-21.
- 19 Colombia. Ley n° 100, de 23 de diciembre de 1993. Por la cual se crea el sistema de seguridad social integral y se dictan otras disposiciones [Internet]. *Diario Oficial, Bogota (CO)*, n° 41.148, 1993 dic 23 [citado 2019 feb 4]. Disponible de: [http://www.secretariassenado.gov.co/senado/basedoc/ley\\_0100\\_1993.html](http://www.secretariassenado.gov.co/senado/basedoc/ley_0100_1993.html).
- 20 Colombia. Ley n° 1388, de 26 de mayo de 2010. Por el derecho a la vida de los niños con cáncer en Colombia [Internet]. *Diario Oficial, Bogota (CO)*, n° 47.721, 2010 mayo 26 [citado 2019 feb 4]. Disponible de: [http://www.secretariassenado.gov.co/senado/basedoc/ley\\_1388\\_2010.html](http://www.secretariassenado.gov.co/senado/basedoc/ley_1388_2010.html).
- 21 Piñeros M, Pardo C, Otero J, Suárez A, Vizcaíno M, Álvarez VH, et al. Protocolo de vigilancia en salud pública de las leucemias agudas pediátricas. *Rev Colomb Cancerol*. 2007;11(4):219-27.
- 22 Yang L, Fujimoto J, Qiu D, Sakamoto N. Childhood cancer in Japan: focusing on trend in mortality from 1970 to 2006. *Ann Oncol*. 2009 Jan;20(1):166-74.
- 23 Bosetti C, Bertuccio P, Chatenoud L, Negri E, Levi F, La Vecchia C. Childhood cancer mortality in Europe, 1970–2007. *Eur J Cancer*. 2010 Jan;46(2):384-94.
- 24 Gupta S, Bonilla M, Fuentes SL, Caniza M, Howard SC, Barr R, et al. Incidence and predictors of treatment-related mortality in paediatric acute leukaemia in El Salvador. *Br J Cancer*. 2009 Apr;100(7):1026-31.
- 25 Silva FF, Zandonade E, Zouain-Figueiredo GP. Analysis of childhood leukemia mortality trends in Brazil, from 1980 to 2010. *J Pediatr (Rio J)*. 2014 Nov-Dec;90(6):587-92.
- 26 Slats AM, Egeler RM, van der Does-van den Berg A, Korbijn C, Hählen K, Kamps WA, et al. Causes of death – other than progressive leukemia – in childhood acute lymphoblastic (ALL) and myeloid leukemia (AML): the Dutch Childhood Oncology Group experience. *Leukemia*. 2005 Apr;19(4):537-44.
- 27 Allemani C, Matsuda T, Di Carlo V, Harewood R, Matz M, Nikšić M, et al. Global surveillance of trends in cancer survival 2000–14 (CONCORD-3): analysis of individual records for 37 513 025 patients diagnosed with one of 18 cancers from 322 population-based registries in 71 countries. *Lancet*. 2018 Mar;391(10125):1023-75.
- 28 Giovanella L, Escorel S, Lobato LVC, Noronha JC, Carvalho AI, organizadores. *Políticas e sistemas de saúde no Brasil*. 2. ed. Rio de Janeiro, RJ: Editora Fiocruz; 2012. 1100 p.
- 29 Schottenfeld D, Fraumeni JF, editores. *Cancer epidemiology and prevention*. 3rd ed. Oxford: Oxford University Press; 2006. 1392 p.
- 30 Krok-Schoen JL, Fisher JL, Stephens JA, Mims A, Ayyappan S, Woyach JA, et al. Incidence and survival of hematological cancers among adults ages  $\geq 75$  years. *Cancer Med*. 2018 Apr;7(7):3425-33.
- 31 Andersson TM-L, Lambert PC, Derolf AR, Kristinsson SY, Eloranta S, Landgren O, et al. Temporal trends in the proportion cured among adults diagnosed with acute myeloid leukaemia in Sweden 1973-2001, a population-based study. *Br J Haematol*. 2010 Mar;148(6):918-24.
- 32 Gómez Baute R, Fernández Águila JD, Dita Salabert L, Guerra Alfonso T. Sobrevida en pacientes con leucemia aguda no linfoblástica en el hospital "Dr. Gustavo Aldereguía Lima". *Experiencia de diez años. MediSur*. 2010 sep-oct;8(5):32-41.
- 33 Public Health Surveillance and Environmental Health Branch, Public Health Division. ICD-9 to ICD-10 coding with reference to causes of death grouping in Alberta: working documentation (version 1.0) [Internet]. Edmonton (CAN): Public Health Surveillance and Environmental Health Branch; 2006 [cited 2019 Apr 16]. (Health surveillance system series). Available from: <https://open.alberta.ca/dataset/5bbd50c0-ed15-4dc8-b51f-affa45b82a17/resource/c69757b3-7bb2-49ed-b7a9-9cfa560ad7e3/download/icd-death-grouping-2007.pdf>.
- 34 García-Ubaque JC, Quintero-Matallana CS. Barreras geográficas y económicas para el acceso a los servicios oncológicos del Instituto Nacional de Cancerología en Bogotá. *Rev Salud Publica (Bogotá)*. 2008 Aug-Oct;10(4):583-92.
- 35 Suárez A, Guzmán C, Villa B, Gamboa Ó. Abandono del tratamiento: una causa de muerte evitable en el niño con cáncer. *Rev Colomb Cancerol*. 2011;15(1):22-9.
- 36 World Health Organization. WHO methods and data sources for country-level causes of death 2000-2016 [Internet]. Geneva: World Health Organization; 2018 [cited 2020 Jun 6]. Available from: [http://terrance.who.int/mediacentre/data/ghe/GlobalCOD\\_method\\_2000\\_2016.pdf?ua=1](http://terrance.who.int/mediacentre/data/ghe/GlobalCOD_method_2000_2016.pdf?ua=1).
- 37 Bravo LE, García LS, Collazos P, Aristizabal P, Ramirez O. Descriptive epidemiology of childhood cancer in Cali, Colombia 1977-2011. *Colomb Med (Cali)*. 2013 Jul-Sep;44(3):155-64.

- 38 World Health Organization. Primary health care systems (PRIMASYS): case study from Colombia [Internet]. Geneva: World Health Organization; 2017 [cited 2020 Jun 6]; Available from: [https://www.who.int/alliance-hpsr/projects/alliancehpsr\\_colombiaprimasys.pdf?ua=1](https://www.who.int/alliance-hpsr/projects/alliancehpsr_colombiaprimasys.pdf?ua=1).
- 39 Vries E, Buitrago G, Quitian H, Wiesner C, Castillo JS. Access to cancer care in Colombia, a middle-income country with universal health coverage. *J Cancer Policy*. 2018 May;15(Pt B):104-112.

Received / Recebido em: 19/9/2019

Accepted / Aceito em: 31/8/2020

*How to cite this article / Como citar este artigo:*

Buitrago ACF, Miranda-Filho AL, Monteiro GTR, Koifman RJ, Santos SS. Leukemia mortality trend in Colombia and its capital city, Bogotá: an ecological study between 1985 and 2012. *Rev Pan Amaz Saude*. 2020;11:e202000480. Doi: <http://dx.doi.org/10.5123/S2176-6223202000480>