Heliyon 9 (2023) e16420

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

CelPress

Increased suicide rates in Mexico City during the COVID-19 pandemic outbreak: An analysis spanning from 2016 to 2021

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ARTICLE INFO

Keywords: SARS-CoV-2 Sex Coroners' record Mental health Long COVID

ABSTRACT

Objective: Coronavirus disease 2019 (COVID-19) has impacted mental health worldwide, and suicide can be a serious outcome of this. Thus, suicide characteristics were examined before and during the COVID-19 pandemic in Mexico City. *Methods:* This is a retrospective study including all Mexico City residents who had a coroner's

record with a cause of death of intentional self-harm (ICD-10) from January 2016 to December 2021. *Results*: From 2016 to 2021, 3636 people committed suicide, of which 2869 were males (78.9%)

and 767 females (21.1%). From 2016 to 2019 the suicide rate remained constant (~6 per 100000) and dramatically increased in 2020 (10.45 per 100,000), to return to the levels of the previous year in 2021 (6.95 per 100000). The suicide rate in 2020 specifically increased from January to June (COVID-19 outbreak) in all age groups. Moreover, every year young people (15–24 years) have the maximum suicide rate and depression was the main suicide etiology.

Conclusion: The COVID-19 pandemic outbreak increased the suicide rate, regardless of age, but suicide prevalence was higher in males and young people, regardless of the COVID-19 pandemic. These findings confirm that suicide is a complex and multifactorial problem and will allow the establishment of new guidelines for prevention and care strategies.

1. Introduction

Since the first reports of a highly contagious and lethal virus, the severe acute respiratory syndrome-related coronavirus 2 (SARS-

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https://doi.org/10.1016/j.heliyon.2023.e16420

Received 30 January 2023; Received in revised form 6 May 2023; Accepted 16 May 2023

Available online 30 May 2023



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 $^{^{1}\,}$ These authors are co-first authors.

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CoV-2), which compromised public health in China at the end of 2019, it was a matter of time before all the countries of the world suffered a health contingency due to coronavirus disease 2019 (COVID-19) [1]. During the early stages of COVID-19, most of the efforts to understand SARS-CoV-2 pathophysiology was focused on its pulmonary and gastrointestinal effects [2]. However, as clinical data were collected, it was evident that SARS-CoV-2 has brain tropism because of the high prevalence of psychiatric and neurological symptoms in patients with COVID-19 [3,4]. Together, brain infection susceptibility to SARS-CoV-2 [5] and stressful conditions due to the COVID-19 pandemic [6] have affected the mental health of the worldwide population.

Suicide is closely related to mental health issues such as anxiety and depression, of which chronic stress is a major risk factor [7]. In such a manner, an increase in deaths by suicide during the COVID-19 pandemic was expected [8]. Interestingly, an initial report by Pirkis and colleagues [9], which analyzed 21 countries classified according to their socioeconomic status by the World Bank as high and upper-middle-income countries, did not find differences in the suicide rate from January 1, 2019, to July 31, 2020 (period for the first wave of the COVID-19 pandemic). Although this socioeconomic classification considered some relevant aspects of COVID-19 outcomes in the analyzed countries, they were not enough for the detailed analyses of the suicide rate during the pandemic. A specific case is Japan, which was included in the Pirkis et al. study [9], where an increase of 14% in the suicide rate during the COVID-19 pandemic was reported (February–June 2020) [10]. This study dissected some sociodemographic characteristics such as age groups and occupation, and the increase in suicide in Japan was confirmed by a recent report by Yoshioka et al. [11]. Other reports with similar considerations have reported an increase in deaths because of suicide in Nepal [12], South Korea [13], Poland [14], and the U. S.A [15,16]. Moreover, in the U.K. it was documented that suicides rate doubled during October–November 2020 [17]. Interestingly all these studies reported several demographics, socioeconomic and clinical conditions which modify suicide rate, such as sex, race, and base income, among others. It is important to note that more than 70% of worldwide suicide cases occur in low- and middle-income countries [18,19], highlighting demographics and socioeconomic factors as robust modulators of suicide prevalence.

This study evaluated the suicide rate in Mexico City from 2016 to 2021, which includes 22 months of the COVID-19 pandemic. Suicide was examined each year by month and per group of age, as well as by sex considering socioeconomic and clinical variables including suicide method, etiology, marital status, education, and ethanol and substance consumption.

2. Methods

2.1. Study setting and data collection

This study included all Mexico City residents who had a coroner's record with a cause of death of intentional self-harm, according to X60–X84 codes of the International Classification of Diseases, 10th Revision (ICD-10). Data were collected from January 2016 to December 2021. Complete records for suicide cases were obtained and analyzed at the Forensics Sciences Institute of Mexico City. This institution has documented suicide cases in Mexico City since 1960 [20]. The records from the coroner's office involving suicides included demographic information, circumstances of the death, acute and chronic stressful life situations, autopsy and toxicology reports, police investigation records, medical, and psychiatric reports from hospitals, and death certificates. This information, included in the coroner's records, was obtained through the victim's families and witness testimonies. For confidentiality purposes, every case received a specific code for each coroner's records and personal data remained inaccessible throughout the study, and only three researchers extracted information from these files, which was only consulted on site.

All the procedures described were approved by the Bio-Ethical Committee for Human Research at the Forensic Science Institute of Mexico City (Conbiética-09-CEI-022-20160823).

2.2. Statistical analysis

Suicide characteristics, as well as socioeconomic and clinical information, were reported based on frequencies and percentages. For the comparisons by sex and year, Chi-square (χ^2) analyses for contingency tables were used. A p-value <0.05 was set as the statistical threshold. Suicide mortality rates were calculated using the number of suicide deaths as the numerator and each year's population by age or sex as the denominator. The population of Mexico City for each year was obtained from the "Consejo Nacional de Población" (CONAPO) database [21], according to the Projections of the Population of the Municipalities of Mexico, 2015–2030, recorded by groups of age and sex (Table 1). Mexican data for COVID-19 was obtained from the Secretary of Health database [22,23] and worldwide data was obtained from the World Health Organization (WHO) Coronavirus (COVID-19) dashboard [24]. Data analysis was performed with Graph Pad Prism 9.0.

3. Results

3.1. Suicide rate increased in 2020, during COVID-19 outbreak

Between January 1st, 2016, to December 31st, 2021, 3636 people committed suicide in Mexico City, of which 2869 were males (78.9%) and 767 females (21.1%). The annual breakdown of the data is shown in Supplement I. Males consistently have a higher number of deaths by suicide (Fig. 1A) and suicide rates each year compared to females (Fig. 1B).

From 2016 to 2018 (~5.42 per 100,000), the suicide rate remained constant and slightly increased in 2019 (6.60 per 100,000). However, it dramatically increased in 2020 (10.45 per 10,000), to return to the levels of previous years in 2021 (6.95 per 100,000) (Fig. 1B). In the monthly analysis of the suicide rate (Fig. 2A), it was detected that the general suicide rate for 2020 was due to the

Table 1

Suicide characteristics, socioeconomic and clinical analysis for 2016-2021, cases and (%). Bold text indicate statistical significance.

	Females	Males	Total	Statistic	Females	Males	Total	Statistic	Females	Males	Total	Statistic					
	2016				2017				2019								
	2010				2017				2018								
	97 (19.32)	405 (80.68)	490 (100)		97 (19.8)	393 (80.2)	490 (100)		106 (22.13)	373 (77.87)	479 (100)						
Suicide methodsrowhead Hanging	75 (77.32)	291 (71.85)	366 (72.91)	$\chi^2 =$	73 (75.26)	279 (70.99)	352	$\chi^2 =$	86	275	361 (75.37)	$\chi^2 = 19.56, df = 5, p =$					
Firearm	5 (5.15)	59 (14.57)	64 (12.75)	df = , p	7 (7.22)	48 (12.21)	(71.84) 55 (11.22)	10.64, df = 5, n = 10.64	(81.13) 6 (5.66)	(73.73) 43 (11.52)	49 (10.23)	0.0015					
Poisoning	5 (5.15)	8 (1.98)	13 (2.59)	 0.0737	0 (0.00)	11 (2.80)	11 (2.24)	p = 0.0591	1 (0.94)	(11.55) 7 (1.88)	8 (1.67)						
White arm	2 (2.06)	6 (1.48)	8 (1.59)		5 (5.15)	5 (1.27)	10 (2.04)		6 (5.66)	(1.88) 2 (0.54)	8 (1.67)						
Trauma	10 (10.31)	37 (9.14)	47 (9.36)		12 (12.37)	49 (12.47)	61 (12.45)		7 (6.60)	43	50 (10.44)						
Others	0 (0)	4 (0.99)	4 (1.00)		0 (0)	1 (0.25)	1 (0.20)		0 (0)	3 (0.81)	3 (0.63)						
Etiologyrowhead Depression	62 (63.92)	264 (65.19)	326 (64.94)	$\chi^2 =$	56 (57.73)	211 (53.69)	267	$\chi^2 =$	39 (26 70)	140	179 (37.37)	$\chi^2 = 6.873, df = 5, p = 0.2303$					
Other psychiatric diagnoses	8 (8.25)	12 (2.96)	20 (3.98)	df = 5,	7 (7.22)	29 (7.38)	36 (7.35)	$\begin{array}{llllllllllllllllllllllllllllllllllll$	(30.79) 12 (11.22)	(37.33)	32 (6.68)						
Family problems	0 (0)	2 (0.49)	2 (0.40)	p = 0.1283	4 (4.12)	5 (1.27)	9 (1.84)		(3.30) 13 (3.49)	16 (3.34)							
Sentimental problems	6 (6.19)	16 (3.95)	22 (4.38)							2 (2.06)	16 (4.07)	18 (3.67)		7 (6.60)	(5.45) 21 (5.63)	28 (5.85)	
Economic problems	0 (0)	1 (0.25)	1 (0.20)		1 (1.03)	4 (1.02)	5 (1.02)		0 (0)	(0.00) 7 (1.88)	7 (1.46)						
Unknown	20 (20.62)	111 (27.41)	131 (26.10)		27 (27.84)	128 (32.57)	155 (31.63)		45 (42.45)	172 (46.11)	217 (45.3)						
Marital status rowhead Single	32 (32.99)	179 (44.20)	211 (42.03)	$\chi^2 =$	38 (39.18)	179 (45.55)	217	$\chi^2 =$	58	169	227 (47.39)	$\chi^2 = 4.328, df = 5 \; p = 0.5032$					
Married	22 (22.68)	103 (25.43)	125 (24.90)	10.13, df = 5, p = 0.071	15 (15.46)	84 (21.37)	(44.29) 99 (20.20)	8.48, df = 5, p = 0.1317	(54.72) 13	(45.31) 69 (18.50) 70 (18.77)	82 (17.12)						
Free union	25 (25.77)	87 (21.48)	112 (22.31)		16 (16.49)	71 (18.07)	87 (17.76)		(12.26) 17		87 (18.16)						
Divorced	7 (7.22)	13 (3.21)	20 (3.98)		5 (5.15)	17 (4.33)	22 (4.49)		3 (2.83)	(10.77) 14 (3.75)	17 (3.55)						
Widower	4 (4.12)	5 (1.23)	9 (1.79)		5 (5.15)	12 (3.05)	17 (3.47)		3 (2.83)	(3.73) 7 (1.88)	10 (2.09)						
Unknown	7 (7.22)	27 (6.67)	34 (6.77)		2 (2.06)	46 (11.70)	48 (9.80)		12 (11.32)	44	56 (11.69)						
Education rowhead College	21 (21.65)	49 (12.10)	70 (13.94)	$\chi 2 = 12.79, \ df = 6,$	20 (20.62)	66 (16.79)	86 (17.55)	$\chi^2 = 4.223, \ df = 6,$	20 (18.87)	72 (19.30)	92 (19.21)	$\chi^2 = 9.020, df = 5, p = 0.1083$					

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	Females	Males	Total	Statist	ic Females	Males	Total	Statistic	Females	Males	Total	Statistic
High school	26 (26.80)	112 (27.65)	138 (27.49)	p =	25 (25.77)	87 (22.14)	112	p =	27	90	117 (24.43)	
Secondary school	35 (36.08)	135 (33.33)	170 (33.86)	0.046	33 (34.02)	129 (32.82)	(22.86) 162 (33.06)	0.6465	(25.47) 19 (17.92)	(24.13) 99 (26.54)	118 (24.63)	
Elementary school	12 (12.37)	62 (15.31)	74 (14.74)		11 (11.34)	60 (15.27)	(33.00) 71 (14.49)		(17.92) 10 (9.43)	(20.34) 48 (12.87)	58 (12.11)	
Incomplete elementary school	1 (1.03)	2 (0.49)	3 (0.60)		0 (0)	1 (0.25)	1 (0.20)		0 (0)	0 (0)	0 (0)	
Without school education	0 (0)	3 (0.74)	3 (0.60)		0 (0)	6 (1.53)	6 (1.22)		1 (0.94)	4 (1.07)	5 (1.04)	
Unknown	2 (2.06)	49 (10.12)	70 (8.57)		8 (8.25)	43 (10.94)	51 (10.41)		29 (27.36)	60 (16.09)	89 (18.58)	
Ethanol rowhead Positive	7 (7.22)	100 (24.69)	107 (21.31)	$\chi^2 = 15.27$	11 (11.34)	57 (14.50)	68 (13.88)	$\chi^2 = 0.7040$	10	64	74 (15.45)	$\chi^2 = 4.415, df = 2, p = 0.11$
Negative	52 (53.61)	158 (39.01)	210 (41.83)	df = 2	2 , 39 (40.21)	157 (39.95)	196 (40.00)	df = 2,	(9.43) 50 (47.17)	(17.10) 175 (46.92)	225 (46.97)	
Unknown	38 (39.18)	147 (36.30)	185 (36.85)	0.000	5 47 (48.85)	179 (45.55)	226	0.703	(1).17) 46 (43.40)	(10.92) 134 (35.92)	180 (37.58)	
Substances rowhead												
Positive	3 (3.09)	46 (11.36)	49 (9.76)	$\chi^2 = 6.166$	10 (10.31)	32 (8.14)	42 (8.57)	$\chi^2 = 1.259,$	8 (7.55)	37 (9.92)	45 (9.39)	$\chi^2 = 1.41, df = 2, p = 0.4942$
Negative	54 (55.67)	200 (49.38)	254 (50.60)	df = 2	2 , 38 (39.18)	177 (45.04)	215 (43.88)	df = 2,	55 (51.89)	206	261 (54.49)	
Unknown	40 (41.24)	159 (39.26)	199 (39.64)	0.045	8 49 (50.52)	184 (46.82)	233 (47.55)	0.5328	(31.05) 43 (40.57)	130 (34.85)	173 (36.12)	
2019					2020				2021			
	118 (19.8)	478 (80.2)	596 (100)		208 (22.08)	734 (77.92)	942 (100)		140 (22.3	486 6) (77.64	626 (100) 4)	
Suicide methodsrowhead												
Hanging	86 (72 88)	357 (74.69)	443 (74-33)	$\chi^2 = 9.58$	160 (76.92)	582 (79.29)	742 (78.77)	$\chi^2 = 27.01$	108	365 4) (75.1(473	$\chi^2 = 24.74, df = 5, p = 0.0002$
Firearm	7 (5.93)	62 (12.97)	69 (11.58)	df = 4, p =	8 (3.85)	74 (10.08)	82 (8.70)	df = 1	5 , 4 (2.8	(9.26) (9.26)	49 (7.83)	0.0002
Poisoning	2 (1.69)	6 (1.26)	8 (1.34)	0.0481	1 (0.48)	14 (1.91)	15 (1.59)	0.000	1 10 (7.14)	5) (1.03)	15 (2.40)	
White arm	5 (4.24)	10 (2.09)	15 (2.52)		6 (2.88)	7 (0.95)	13 (1.38)		0 (0)	7 (1.44)	7 (1.12)	
Trauma	18 (15.25)	43 (9.00)	61 (10.23)		28 (13.46)	53 (7.22)	81 (8.60)		17 (12.1-	60 4) (12.35	77 (12.30)	
Others	0 (0)	0 (0)	0 (0)		5 (2.40)	4 (0.55)	9 (0.10)		1 (0.7	(0.82)	5 (0.80)	
Etiologyrowhead	41	169 (35 36)	210	$x^2 -$	83 (30 00)	263 (35 83)	346 (36 73)	$x^2 -$	45	160	214	$x^2 - 15.08 df - 5 p - 0.01$
Depression	(34.75)	107 (33.30)	(35.23)	λ — 17.49,	00 (09.90)	203 (33.63)	370 (30.73)	$\lambda = 15.56$, (32.14	4) (34.77	7) (34.19)	$\lambda = 15.00, \text{ m} = 5, \text{ p} = 0.01$
Other psychiatric diagnoses	20 (16.95)	30 (6.28)	50 (8.39)	df = 5,	30 (14.42)	53 (7.22)	83 (8.81)	df =	5, 29 (20.7	44 1) (9.05)	73 (11.66)	
												(continued on next page)

	Females	Males	Total	Statis	stic Females	Males	Total	Statistic F	emales M	Iales T	otal	Statistic
								-				
Family problems	7 (5.93)	22 (4.60)	29 (4.87)	p = 0.0037	12 (5.77)	36 (4.90)	48 (5.10)	p = 0.0082	7 (5.00)	29 (5.97)	36 (5.75)	
Sentimental problems	7 (5.93)	29 (6.07)	36 (6.04)		13 (6.25)	67 (9.13)	80 (8.49)		10 (7.14)	33 (6.79)	43 (6.87)	
Economic problems	0 (0)	10 (2.09)	10 (1.68)		2 (0.96)	11 (1.50)	13 (1.38)		3 (2.14)	10 (2.06)	13 (2.08)	
Unknown	43 (36.44)	218 (45.61)	261 (43.79)		68 (32.69)	304 (41.42)	372 (39.49)		46 (32.86)	201 (41.36)	247 (39.46)	
Marital statusrowhead												
Single	64 (54.24)	216 (45.19)	280 (46.98)	$\chi^2 = 20.65,$	104 (50.00)	350 (47.68)	454 (48.20)	$\chi^2 = 24.12,$	52 (37.14)	204 (41.98)	256 (40.89)	$\chi^2 = 7.275, df = 5, p = 0.201$
Married	7 (5.93)	105 (21.97)	112 (18.79)	df = 5, p =	33 (15.87)	144 (19.62)	177 (18.79)	df = 5, p =	28 (20.00)	86 (17.70)	114 (18.21)	
Free union	30 (25.42)	101 (21.13)	131 (21.98)	0.0009	42 (20.19)	117 (15.94)	159 (16.88)	0.0002	26 (18.57)	93 (19.14)	119 (19.01)	
Divorced	3 (2.54)	18 (3.77)	21 (3.52)		7 (3.37)	40 (5.45)	47 (4.99)		4 (2.86)	28 (5.76)	32 (5.11)	
Widower	5 (4.24)	14 (2.93)	19 (3.19)		4 (1.92)	14 (1.91)	18 (1.91)		1 (0.71)	9 (1.85)	10 (1.60)	
Unknown	2 (1.69)	31 (6.49)	33 (5.54)		2 (0.96)	85 (11.58)	87 (9.24)		29 (20.71)	66 (13.58)	95 (15.17)	
Education rowhead												
College	57 (48.31)	59 (12.34)	116 (19.46)	$\chi^2 = 61.33,$	44 (21.15)	125 (17.03)	169 (17.94)	$\chi^2 = 16.48,$	37 (26.43)	73 (15.02)	110 (17.57)	$\chi^2 = 19.79, df = 6, p = 0.003$
High school	38 (32.20)	124 (25.94)	162 (27.18)	df = 6, p <	69 (33.17)	205 (27.93)	274 (29.09)	df = 6, p =	44 (31.43)	146 (30.04)	190 (30.35)	
Secondary school	27 (22.88)	152 (31.80)	179 (30.03)	0.0001	67 (32.21)	236 (32.15)	303 (32.17)	0.0114	38 (27.14)	143 (29.42)	181 (28.91)	
Elementary school	9 (7.63)	71 (14.85)	80 (13.42)		18 (8.65)	113 (15.40)	131 (13.91)		15 (10.71)	76 (15.64)	91 (14.54)	
Incomplete elementary school	0 (0)	1 (0.21)	1 (0.17)		2 (0.96)	1 (0.14)	3 (0.32)		2 (1.43)	1 (0.21)	3 (0.48)	
Without school education	0 (0)	4 (0.84)	4 (0.67)		2 (0.96)	4 (0.54)	6 (0.64)		0 (0)	2 (0.41)	2 (0.32)	
Unknown	7 (5.93)	46 (9.62)	53 (8.89)		6 (2.88)	50 (6.81)	56 (5.94)		4 (2.86)	45 (9.26)	49 (7.83)	
Ethanolrowhead												
Positive	26 (22.03)	128 (26.78)	154 (25.84)	$\chi^2 = 1.112,$	44 (21.15)	230 (31.34)	274 (29.09)	$\chi^2 = 9.371,$	15 (10.71)	91 (18.72)	106 (16.93)	$\chi^2 = 7.95, df = 2, p = 0.0188$
Negative	76 (64.41)	289 (60.46)	365 (61.24)	df = 2, p =	143 (68.75)	422 (57.49)	565 (59.98)	df = 2, p =	80 (57.14)	219 (45.06)	299 (47.76)	
Unknown	16 (13.56)	61 (12.76)	77 (12.92)	0.5736	21 (10.10)	82 (11.17)	103 (10.93)	0.0092	45 (32.14)	176 (36.21)	221 (35.30)	
Substances rowhead											. ,	
Positive	11 (9.32)	42 (8.79)	53 (8.89)	$\chi^2 = 0.1, df$	16 (7.69)	60 (8.17)	76 (8.07)	$\chi^2 = 0.0955,$	6 (4.29)	26 (5.35)	32 (5.11)	$\chi^2 = 1.232, df = 2, p = 0.5401$
Negative	92 (77.97)	379 (79.29)	471 (79.03)	= 2, p =	170 (81.73)	593 (80.79)	763 (81.00)	df = 2, p =	89 (63.57)	284 (58.44)	373 (59.58)	
Unknown	15 (12.71)	57 (11.92)	72 (12.08)	0.9512	22 (10.58)	81 (11.04)	103 (10.93)	0.9533	45 (32.14)	176 (36.21)	221 (35.30)	

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increase in the months from January to June. From 2016 to 2018 peaks were observed in August 2016, April, October, and December 2017, April 2019, and May, September, and November 2019 (Fig. 2A). The analysis of a group of ages revealed that suicide was highest in the 15-19-year-old age group in 2018, in the rest of the years suicide was highest in the 20-24-year-old age group (Fig. 2B). Also, suicide rates in 2020 were higher than in any other year in all the age groups (Fig. 2B). Interestingly, in 2019, suicide rates increased in the 15-44-year-old age group in comparison to the previous years studied (Fig. 2B).

The monthly suicide rate by sex analysis was assessed for each year (Fig. 2C). In 2016, the maximum suicide rate was in August (0.64 per 100,000) for the total population and males (1.09 per 100,000), and in June (0.25 per 100,000) for females. In 2017, the total population maximum suicide rate (0.59 per 100,000) was detected in December, while October and December were the highest suicide rates (0.97 per 100,000) for males, and July for females (0.25 per 100,000). In 2018, the maximum suicide rate was in December (0.54 per 100,000) for the total population and for males (0.95 per 100,000). In 2018, the maximum suicide rate was in December (0.54 per 100,000) for the total population and for males (0.95 per 100,000), and in April and October (0.3 per 100,000) for females. In 2019, the suicide rate for the total population (0.71 per 100,000), females (0.3 per 100,000), and males (1.16 per 100,000) was highest in May. In 2020, the highest suicide rate was detected in the first semester, compared with previous years and the second semester of 2020, in both females and males with values above 0.5 and 1.5 and even 2.0 per 100,000 respectively. Finally, in 2021, March was the month with the highest suicide rate in total and for the male population (0.82 and 1.44 per 100,000 respectively) and February for females (0.32 per 100,000).

3.2. Young people have higher suicide rate regardless of the COVID-19 pandemic

Also, the suicide rate for age groups was estimated for each year (Fig. 2D). In every year included in this study, the suicide rate in males was higher for all the groups of age (except ≤ 9 and 10–14 years) in comparison to females and the total population. In 2016, the suicide rate was highest in the 20-24-year-old age group for females (4.08 per 100,000), males (17.76 per 100,000), and the total population (11 per 100,000). Then, the suicide rate decreased to 49 years and increased in the 50-59-year-old age group. Interestingly, opposite trends were detected by sex, while in males the suicide rate decreased at 45–49 and 59–64 years, it increased in females. In 2017, the highest suicide rate was the 20-24-year-old age group for females (5.26 per 100,000), males (15.1 per 100,000), and the total population (10.25 per 100,000). Two other peaks were detected in the male suicide rate in the 35–39 (14.2 per 100,000) and 45–49 -year-old age group (13.21 per 100,000), while in females in the 30–34, 45–49, 55–59, and \geq 65-year-old age group were significantly lower (<0.8 per 100,000). In 2018, the total population suicide rate was highest at 15–19 years (10.02 per 100,000), in coherence with the female population (8.01 per 100,000) but not with males, in which the highest suicide rate was for the 20-24-year-old age group (16.23 per 100,000). Suicide rates for 2018 decreased after the peak. In 2019, the maximum suicide rate for the total population and for males was in the 20-24-year-old age group (11.95 and 18.54 per 100,000 respectively), and for females in the 15-19-year-old age group (7.52 per 100,000). Total and male suicide rates remained above 8 and 14 per 100,000 respectively from the 15-44-year-old age group (7.52 per 100,000). Total and male suicide rates remained above 8 and 14 per 100,000 respectively from the 15-44-year-old age



Fig. 1. The number of suicides (A) and suicide rates (B) in Mexico City from 2016 to 2021.

group, decreased from the 45-64-year-old age group, and increased at \geq 65 years old. In 2020, the highest suicide rate for the total population and males was in the 20-24-year-old age group (18.87 and 26.95 per 100,000 respectively), and for females in the 15-19-year-old age group (11.47 per 100,000). After the peak, suicide rates decreased, but always with values above the rest of the studied years. Finally, in 2021 the maximum suicide rate for the total population and males was in the 20-24-year-old age group (13.31 and 19.29 per 100,000 respectively), and for females in the 15-19-year-old age group (8.43 per 100,000).

3.3. Depression is the main suicide etiology regardless of the COVID-19 pandemic and in 2020 ethanol-positive suicide cases increased, mainly in males

Table 1 contains the sociodemographic analysis of suicide for each year by sex. In every studied year hanging was the main suicide method (above 70%) and depression was the main etiology (above 32%) regardless of sex. In 2016 (Table 1) suicide was higher in females with a college education (21.65% vs 12.10%). In 2017 (Table 1), no differences were detected. In 2018 (Table 1), only differences among suicide methods by sex were detected, since more males used firearms and traumatic injuries for suicide (11.53% vs 5.66% and 6.60% respectively). In 2019, 2020, and 2021 (Table 1), more sociodemographic factors varied by sex in comparison with previous years. Regarding suicide methods, in these 3 years, suicide by firearm injury was higher in males (2019: 12.97% vs 5.93%, 2020: 10.08% vs 3.85%, 2021: 9.26% vs 2.86%), and in 2019 and 2020 deaths by jumping from heights and the consequently traumatic injuries were higher in females (2019: 15.25% vs 9.0%, 2020: 13.46% vs 7.22%). Moreover, from 2019 to 2021 suicide was higher in females with another psychiatric condition other than depression (2019: 16.95% vs 6.28%, 2020: 14.42% vs 7.22, 2021: 20.71% vs 9.05). Interestingly, 2020 (COVID-19 outbreak year) was not the year with the highest proportion of depression-related suicides (36.73%), it was 2016 (64.94%). In 2019, suicide was higher in married males (2019: 48.31% vs 12.34%, 2020: 21.15% vs 17.03%, 2021: 26.43% vs 15.02%) who died by suicide was higher than males. Finally, in 2020 and 2021 more males who died by suicide tested positive for ethanol (2020: 31.34% vs 21.15%, 2021: 18.72% vs 10.71%), and 2020 was the year with the largest proportion of ethanol-positive suicides (29.09%).



Fig. 2. Suicide rates for each month (A) and per group of age (B) in Mexico City from 2016 to 2021. Monthly analysis of suicide rates by sex for each year (C). Age group analysis of suicide rates by sex for each year (D).



Fig. 3. Temporal profile sociodemographic and clinical characteristics of suicide by sex. Suicide methods (A), etiology (B), marital status (C), scholarity (D), ethanol test (E), and substance test (F). Abbreviations: C, college; D, divorced; EP, economic problems; ES, elementary school; FP, family problems; FU, free union; HS, high school; IES, incomplete elementary school; M, married; OPD, other psychiatric diagnoses; S, single; SC, secondary school; SP, sentimental problems; W, widower; WOE, without school education.

Additionally, comparisons for suicide methods (females: $\chi^2 = 48.97$, df = 25, p = 0.0029; males: $\chi^2 = 38.8$, df = 25, p = 0.0386), etiology (females: $\chi^2 = 60.95$, df = 25, p < 0.0001; males: $\chi^2 = 178.6$, df = 25, p < 0.0001), marital status (females: $\chi^2 = 94.24$, df = 25, p < 0.0001; males: $\chi^2 = 46.5$, df = 25, p = 0.0056), education (females: $\chi^2 = 137.3$, df = 30, p < 0.0001; males: $\chi^2 = 48.77$, df = 30, p < 0.0001), ethanol consumption (females: $\chi^2 = 92.61$, df = 10, p < 0.0001; males: $\chi^2 = 278.5$, df = 10, p < 0.0001), and substance consumption (females: $\chi^2 = 95.27$, df = 10, p < 0.0001; males: $\chi^2 = 312$, df = 10, p < 0.0001) by year resulted in statistical significance differences for all cases. For visualization proposes, these data are presented in Fig. 3.

Regarding suicide methods (Fig. 3A), the use of firearms tended to decrease in the total population and poisoning substantially increase only in females by 2021. A robust decrease in suicide by trauma in females and males occurred in 2018, and after reaching a maximum in 2018, suicides by white arm consistently decreased by 2021. Regarding suicide etiology (Fig. 3B), depression-related cases decreased from their maximum in 2016 until 2018 and remained constant by 2021 in the total population. However, suicides related to other psychiatric diagnoses increased by 2021, the year in which reached its maximum level, and this was more evident in females. Data on marital status (Fig. 3C) revealed that suicide in married females decreased by 2021 after its maximum level in 2018. Education level analysis (Fig. 3D) revealed that in 2019 suicide drastically increased in females with college studies. Finally, suicides cases in which ethanol (Fig. 3E) and substance consumption (Fig. 3F) were positive reached minimum levels in 2019 and 2021, but substantially increased in 2021.

4. Discussion

In this study, we found that the number of suicides and suicide rates increased in 2019 and substantially increased in 2020 in comparison with 2016 to 2018 data in Mexico City. The 2020 suicide rate increase was specifically in the first six months of the year, which corresponds to the outbreak of the COVID-19 pandemic. However, suicide rates increased in all age groups during 2020, in comparison with 2016–2019 and 2021. Monthly analysis of suicide data revealed that the suicide rate is higher in males. The analysis by age groups showed that the ages with the highest suicide rate are in the 20 to 24-year-old age group, followed by the 15 to 19-year-old age group.

Suicide is a public health problem not only because of its complex epidemiology which includes demographic, genetic, clinical, and environmental variables, but also because of the stigma about suicide [25]. Recent studies have shed light on suicide neurobiology, which points to diverse neuroendocrine (i.e. hypothalamic–pituitary–adrenal axis alterations) and neurotransmitter (i.e. serotonin and dopamine) disfunction [26]. However, this neurobiological mechanism must interact with environmental stimuli to set suicide behavior, and a myriad of environmental aspects have been associated with suicide, including sociodemographic and economic features [25]. Thus, suicide has regional characteristics which must be analyzed to design and implement successful public health strategies to control it.

In Mexico City, considering the total population, the number of suicides and suicide rates per 100,000 remained constant from 2016 to 2018 (Fig. 1), and 2018 was the year with a lowest suicide rate during this period (Table 1). In 2019, the suicide rate increased by 22.77%, compared with the mean suicide rate of 2016–2018 (5.42 per 100,000). However, in 2020, the suicide rate increased by 58.3% in comparison with 2019. The main factor attributed to this boost in the suicide rate is the COVID-19 pandemic.

The context of COVID-19 pandemic in Mexico City is the following [22,23], the first COVID-19 cases and deaths were confirmed on February 27th and on March 22nd² 2020. On March 23rd, national preventive infection strategies without restrictive measures were implemented, and on April 1st a national health emergency phase was declared, implementing restrictive measures, including lockdown. Then, two infection peaks were detected in May 2020 (~1100 daily cases) and January 2021 (~7400 daily cases). Regarding COVID-19-related daily deaths, the first peak was reached in May 2020 (~170). From the end of July to the first week of November 2020, daily deaths remained around 50 and then increased until they reached their peak in January 2021 (~270), which was the maximum number of deaths registered in the pandemic (until June 2022). Finally, the national vaccination campaign against COVID-19 started on December 24th, 2020.

Despite a higher suicide rate in 2020 in comparison with previous years, this increase was only in the first semester of the year, from January to June (Fig. 2A). Thus, the increase in suicide rate in 2020 corresponded with the increase in deaths from the COVID-19 outbreak.

There are several reports of people suffering anxiety and depression during the COVID-19 pandemic [27]. Moreover, some studies reported that adolescents and young adults were vulnerable to this, which is congruent with our findings, since despite an increased suicide rate in all the age groups in 2020, it was higher in the groups from 15 to 29 years old (Fig. 2B). Various reports from different countries revealed that young people, around 18–34 years old, were vulnerable to stress, anxiety, and depression during the COVID-19 pandemic [28–34], including Mexico [35,36].

Also, it was reported that social isolation was a main factor for mental health and school problems during COVID-19 outbreak in the student population (6–18 years old) in Mexico City. This is mainly due to the lack of quality internet services and computer access, which compromise the academic performance of the students [37]. These problems could even be more severe in communities with less telecommunication infrastructure than Mexico City, which is the capital of the country, as documented in some indigenous communities [38]. Also, social isolation during the COVID-19 pandemic affected sleep quality and caused anxiety and depression-related symptoms in people from 18 to 40 years old [39].

Moreover, ethanol consumption has been associated with an increased suicide risk in vulnerable people, such as patients with psychiatric diagnoses, people living in high COVID-19 prevalence areas, etc. [8]. Thus, it can be interpreted that stress, anxiety, and depression due to COVID-19, together with ethanol consumption, may be risk factors that could increase suicide rates.

Here we found that suicide increased during the COVID-19 pandemic, together with the reports from other countries, as mentioned

in the introduction (Section 1). However, suicide rates were modified by diverse economic, demographic, and social factors [15,40, 41]. In Poland, a study performed on the university student population (18–24 years) detected an increase in the suicide rate only in males during the first 2 months of the COVID-19 pandemic [14]. In Japan, the 20-29-year-old age group had the largest increase in rate change in suicide and estimated number of cumulative excess deaths by suicide during the COVID-19 pandemic [11]. Here we report that the suicide rate substantially increased in age groups from 18 to 24 years old during 2020, and the highest suicide rate was in age groups in the other analyzed years. Previous studies of our group in the Mexico City population suggest an HPA dysfunction in young suicide completers, since hypertrophy and oxidative stress in the adenohypophysis were detected in *postmortem* tissue [42]. Also, young-adult suicide attempters have increased cortisol blood levels in comparison with a control group [43]. This supports the hypothesis that young people are a vulnerable group to suicide apart from the COVID-19 pandemic.

During the COVID-19 outbreak, worldwide healthcare professionals were a vulnerable group due to problems related to mental health [44–46]. In Mexico City healthcare workers under 40 years old, depression, insomnia, and posttraumatic stress disorder (PTSD) were reported as the main mental health consequences related to the COVID-19 pandemic [47,48]. In the present study we were unable to analyze the occupation of the suicide completers and we discuss this point in the limitations of the study (Section 5).

However, suicide did not increase across the board worldwide due to COVID-19 [49,50]. In Canada, a reduction in the suicide rate was reported due to a national strategy for prevention [51]. This is interesting, since we detected an increase in the suicide rate during specific months of the COVID-19 pandemic (2020), from January to June, and October. In the rest of 2020 suicide was equal to or even lower than reported in previous years. Fear of suffering from COVID-19 was the main factor for the increase in anxiety and cases of depression in India [52], and a factor contributing to suicide in India [53], and Pakistan [41]. This neuropsychological factor was evident in the first stages of the pandemic when there was a lot of uncertainty about health and economical COVID-19-related outcomes. Thus, something similar could explain the sudden increase in the suicide rate in the Mexico City population. Interestingly, a national study that evaluated depression (Depression Anxiety and Stress Scale 21: DASS 21) and resilience (14-item Resilience Scale: RS-14) through an online questionnaire from May to June 2020 revealed lower levels of anxiety and depression, and high resilience in the Mexican population in comparison with the Turkish and Chinese populations [54]. Although this was a national study, this data suggest that the first months of the COVID-19 outbreak were critical for mental health and might be associated with the increase in the suicide rate in the first semester of 2020, then resilience might be associated with the decrease in the suicide rate for the second semester of 2020.

In Mexico City, it was detected a reduction in depression-related suicide during the COVID-19 pandemic years. A similar trend was detected in South Korea [50], however, in this population, the number of suicides decreased during the pandemic. Interestingly, in Mexico City, suicide cases related to other psychiatric diagnoses, not including depression, increased during the pandemic, the increase being greater in the female population. This is congruent with a systematic review conducted on the Mexican population which detected young females as the most vulnerable population for mental health outcomes of the COVID-19 pandemic [36].

Beyond the context of the COVID-19 pandemic, suicide prevalence is higher in young people (<30 years old), but also in low- and middle-income countries [18] (Mexico is classified as a middle-income country [55]). For these countries, economic problems are commonly associated with suicide, around 10% of the yearly cases [56,57]. In this report, we found that economic problems never exceed 2.5% of the cases, suggesting that other factors may be contributing to suicide in Mexico City. Additionally, our data confirm some results about suicide in Mexico City from 2014 to 2015 [58]. First, males have a higher suicide rate than females. Second, hanging is the most common method of suicide. Furthermore, during 2016, 2017, and 2019 (in which was most evident), a suicide rate increase at \geq 65 years was detected.

With adequate strategies and interventions, suicide can be prevented. Ultimately these data can contribute to developing suicide prevention strategies, which can be both at population levels, focusing on suicide methods and socioeconomic factors, and individual interventions, targeting psychopathology related to the etiology of suicide. Also, since suicide prevalence is higher in the young population, the implementation of suicide prevention strategies in schools may be critical for the attenuation of this problem [18,59].

5. Limitations

As previously pointed out [58], due to the lack of information from the coroners' records, it was not possible to carry out a more detailed analysis of some specific factors related to suicide and COVID-19. For example, regarding occupation, a couple of reports suggest a mental health problems vulnerability in Mexico City health professionals during the pandemic [47,48]. Moreover, there is a debate about the impact of the pandemic on people with mental diseases, as some reports suggested that mental disease diagnosis increased the risk for worse COVID-19 outcomes [60–62], and other reports do not [63–67]. Moreover, differences in COVID-19 prevalence in Mexican people with mental diseases has been reported [68]. Thus, it would have been interesting to explore the relationship between diagnosing suicide and mental diseases during the COVID-19 pandemic.

6. Conclusions

The outbreak of the COVID-19 pandemic (January to June 2020) increased the suicide rate, regardless of age, in Mexico City. Suicide prevalence was higher in males and young people (15–24 years), beyond the COVID-19 pandemic. Ethanol-positive cases in suicide completers were the highest in 2020, which may be related to the increase in suicide during the COVID-19 pandemic. Moreover, in 2020–2021 more males who died by suicide tested positive for ethanol. These findings confirm that suicide is a complex and multifactorial problem and will allow for the establishment of new guidelines for the development and implementation of prevention and care strategies.

Author contribution statement

Fernando García-Dolores: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Hiram Tendilla-Beltrán: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Francisco Flores; Linda Carbajal-Rimoldi; Roberto Cuauhtémoc Mendoza-Morales; Andrea Judith Vázquez-Hernández; Alma Delia Genis-Mendoza: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Laura Eréndira Gómez-Mendoza; Fidel de la Cruz; Humberto Nicolini: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Gonzalo Flores: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data included in article/supp. material/referenced in article.

Fundings

This work was supported by PRODEP (CA-BUAP-120) and the CONACYT Grant (252808) for Gonzalo Flores. Hiram Tendilla-Beltrán is funded by CONACYT's "Estancias Posdoctorales por México" program (662350). None of the funding institutions had any further role in the study design, the collection of data, analyses, and interpretation of data, writing of the report, or in the decision to submit the paper for publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Hiram Tendilla-Beltrán, Fidel de la Cruz, Alma Delia Genis-Mendoza, Humberto Nicolini, and Gonzalo Flores acknowledge the "Sistema Nacional de Investigadores" of Mexico for memberships. Thanks to Prof. Robert Simpson for the English language edition.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e16420.

References

- Y.-C. Liu, R.-L. Kuo, S.-R. Shih, COVID-19: the first documented coronavirus pandemic in history, Biomed. J. 43 (2020) 328–333, https://doi.org/10.1016/j. bj.2020.04.007.
- [2] M.K. Bohn, A. Hall, L. Sepiashvili, B. Jung, S. Steele, K. Adeli, Pathophysiology of COVID-19: mechanisms underlying disease severity and progression, Physiology 35 (2020) 288–301, https://doi.org/10.1152/physiol.00019.2020.
- [3] S. Lopez-Leon, T. Wegman-Ostrosky, C. Perelman, R. Sepulveda, P.A. Rebolledo, A. Cuapio, S. Villapol, More than 50 long-term effects of COVID-19: a systematic review and meta-analysis, Sci. Rep. 11 (2021), 16144, https://doi.org/10.1038/s41598-021-95565-8.
- [4] G. Flores, SARS-COV-2 (COVID-19) has neurotropic and neuroinvasive properties, Int. J. Clin. Pract. 2 (2020) 1–2, https://doi.org/10.1111/ijcp.13708.
 [5] Y. Xie, E. Xu, Z. Al-Aly, Risks of mental health outcomes in people with covid-19: cohort study, BMJ (2022), e068993, https://doi.org/10.1136/bmj-2021-068993
- [6] O. Giuntella, K. Hyde, S. Saccardo, S. Sadoff, Lifestyle and mental health disruptions during COVID-19, Proc. Natl. Acad. Sci. USA 118 (2021), https://doi.org/ 10.1073/pnas.2016632118.
- [7] L. Brådvik, Suicide risk and mental disorders, Int. J. Environ. Res. Publ. Health 15 (2018) 2028, https://doi.org/10.3390/ijerph15092028.
- [8] L. Sher, The impact of the COVID-19 pandemic on suicide rates, QJM An Int. J. Med. 113 (2020) 707–712, https://doi.org/10.1093/qjmed/hcaa202.
- [9] J. Pirkis, A. John, S. Shin, M. DelPozo-Banos, V. Arya, P. Analuisa-Aguilar, L. Appleby, E. Arensman, J. Bantjes, A. Baran, J.M. Bertolote, G. Borges, P. Brečić, E. Caine, G. Castelpietra, S.-S. Chang, D. Colchester, D. Crompton, M. Curkovic, E.A. Deisenhammer, C. Du, J. Dwyer, A. Erlangsen, J.S. Faust, S. Fortune, A. Garrett, D. George, R. Gerstner, R. Gilissen, M. Gould, K. Hawton, J. Kanter, N. Kapur, M. Khan, O.J. Kirtley, D. Knipe, K. Kolves, S. Leske, K. Marahatta, E. Mittendorfer-Rutz, N. Neznanov, T. Niederkrotenthaler, E. Nielsen, M. Nordentoft, H. Oberlerchner, R.C. O'Connor, M. Pearson, M.R. Phillips, S. Platt, P. L. Plener, G. Psota, P. Qin, D. Radeloff, C. Rados, A. Reif, C. Reif-Leonhard, V. Rozanov, C. Schlang, B. Schneider, N. Semenova, M. Sinyor, E. Townsend, M. Ueda, L. Vijayakumar, R.T. Webb, M. Weerasinghe, G. Zalsman, D. Gunnell, M.J. Spittal, Suicide trends in the early months of the COVID-19 pandemic: an interrupted time-series analysis of preliminary data from 21 countries, Lancet Psychiatr, 8 (2021) 579–588, https://doi.org/10.1016/S2215-0366(21)00091-2.
- [10] T. Tanaka, S. Okamoto, Increase in suicide following an initial decline during the COVID-19 pandemic in Japan, Nat. Human Behav. 5 (2021) 229–238, https:// doi.org/10.1038/s41562-020-01042-z.
- [11] E. Yoshioka, S.J.B. Hanley, Y. Sato, Y. Saijo, Impact of the COVID-19 pandemic on suicide rates in Japan through December 2021: an interrupted time series analysis, Lancet Reg. Heal. - West. Pacific. 24 (2022), 100480, https://doi.org/10.1016/j.lanwpc.2022.100480.
- [12] B. Acharya, K. Subedi, P. Acharya, S. Ghimire, Association between COVID-19 pandemic and the suicide rates in Nepal, PLoS One 17 (2022), e0262958, https:// doi.org/10.1371/journal.pone.0262958.

- [13] J.-H. Kang, S.-W. Lee, J.-G. Ji, J.-K. Yu, Y.-D. Jang, S.-J. Kim, Y.-W. Kim, Changes in the pattern of suicide attempters visiting the emergency room after COVID-19 pandemic: an observational cross sectional study, BMC Psychiatr. 21 (2021) 571, https://doi.org/10.1186/s12888-021-03570-y.
- [14] A. Debowska, B. Horeczy, D. Boduszek, D. Dolinski, A repeated cross-sectional survey assessing university students' stress, depression, anxiety, and suicidality in the early stages of the COVID-19 pandemic in Poland, Psychol. Med. (2020) 1–4, https://doi.org/10.1017/S003329172000392X.
- [15] M.J.C. Bray, N.O. Daneshvari, I. Radhakrishnan, J. Cubbage, M. Eagle, P. Southall, P.S. Nestadt, Racial differences in statewide suicide mortality trends in Maryland during the coronavirus disease 2019 (COVID-19) pandemic, JAMA Psychiatr. 78 (2021) 444, https://doi.org/10.1001/jamapsychiatry.2020.3938.
- [16] M.-L. Charpignon, J. Ontiveros, S. Sundaresan, A. Puri, J. Chandra, K.D. Mandl, M.S. Majumder, Evaluation of suicides among US adolescents during the COVID-19 pandemic, JAMA Pediatr. (2022), https://doi.org/10.1001/jamapediatrics.2022.0515.
- [17] D. Vinnakota, A.D. Parsa, S.M.Y. Arafat, M. Sivasubramanian, R. Kabir, COVID-19 and risk factors of suicidal behavior in UK: a content analysis of online newspaper, J. Affect. Disord. Reports. 4 (2021), 100142, https://doi.org/10.1016/j.jadr.2021.100142.
- [18] J. Renaud, S.L. MacNeil, L. Vijayakumar, M. Spodenkiewicz, S. Daniels, D.A. Brent, G. Turecki, Suicidal ideation and behavior in youth in low- and middleincome countries: a brief review of risk factors and implications for prevention, Front. Psychiatr. 13 (2022), https://doi.org/10.3389/fpsyt.2022.1044354.
- [19] M. Mohammadnezhad, A. Konrote, R. Kabir, Determinants of suicide in pacific region and needs for considering equality amongst pacific people: a systematic review, Pacific J. Med. Sci. 19 (2018) 17–29.
- [20] Algunos datos hitóricos de la medicina legal y forense en México, 2009. http://www.consejomexicanodemedicinalegal.com.mx/consejo/m1.htm. March, 2023.
 [21] Consejo Nacional de Población, Proyecciones de la Población de México y de las Entidades Federativas, 2016-2050, 2018. https://datos.gob.mx/busca/dataset/proyecciones-de-la-poblacion-de-mexico-y-de-las-entidades-federativas-2016-2050.
- [22] Secretaría de Salud, Coronavirus gob.mx (n.d.), https://datos.covid-19.conacyt.mx/. June, 2022.
- [23] G.M. Secretaría de Salud, 34º Informe epidemiológico de la situación de COVID-19. Dirección de información epidemiológica, 25 de octubre de 2021, 2021. https://www.gob.mx/cms/uploads/attachment/file/604439/Informe_COVID-19_2021.01.04.pdf.
- [24] World Health Organization, WHO Coronavirus (COVID-19) Dashboard (n.d.), https://covid19.who.int/. June, 2022.
- [25] E. DiBlasi, J. Kang, A.R. Docherty, Genetic contributions to suicidal thoughts and behaviors, Psychol. Med. 51 (2021) 2148–2155, https://doi.org/10.1017/ S0033291721001720.
- [26] K. van Heeringen, J.J. Mann, The neurobiology of suicide, Lancet Psychiatr. 1 (2014) 63-72, https://doi.org/10.1016/S2215-0366(14)70220-2.
- [27] D.F. Santomauro, A.M. Mantilla Herrera, J. Shadid, P. Zheng, C. Ashbaugh, D.M. Pigott, C. Abbafati, C. Adolph, J.O. Amlag, A.Y. Aravkin, B.L. Bang-Jensen, G. J. Bertolacci, S.S. Bloom, R. Castellano, E. Castro, S. Chakrabarti, J. Chattopadhyay, R.M. Cogen, J.K. Collins, X. Dai, W.J. Dangel, C. Dapper, A. Deen, M. Erickson, S.B. Ewald, A.D. Flaxman, J.J. Frostad, N. Fullman, J.R. Giles, A.Z. Giref, G. Guo, J. He, M. Helak, E.N. Hulland, B. Idrisov, A. Lindstrom, E. Linebarger, P.A. Lotufo, R. Lozano, B. Magistro, D.C. Malta, J.C. Manson, F. Marinho, A.H. Mokdad, L. Monasta, P. Naik, S. Nomura, J.K. O'Halloran, S. M. Ostroff, M. Pasovic, L. Penberthy, R.C. Reiner Jr., G. Reinke, A.L.P. Ribeiro, A. Sholkhov, R.J.D. Sorensen, E. Varavikova, A.T. Vo, R. Walcott, S. Watson, C. S. Wiysonge, B. Zigler, S.I. Hay, T. Vos, C.J.L. Murray, H.A. Whiteford, A.J. Ferrari, Global prevalence and burden of depressive and anxiety disorders in 204 countries and territories in 2020 due to the COVID-19 pandemic, Lancet 398 (2021) 1700–1712, https://doi.org/10.1016/S0140-6736(21)02143-7.
- [28] P. Varma, M. Junge, H. Meaklim, M.L. Jackson, Younger people are more vulnerable to stress, anxiety and depression during COVID-19 pandemic: a global cross-sectional survey, Prog. Neuro-Psychopharmacol. Biol. Psychiatry 109 (2021), 110236, https://doi.org/10.1016/j.pnpbp.2020.110236.
- [29] N. Salari, A. Hosseinian-Far, R. Jalali, A. Vaisi-Raygani, S.S. Rasoulpoor, M. Mohammadi, S.S. Rasoulpoor, B. Khaledi-Paveh, Prevalence of stress, anxiety, depression among the general population during the COVID-19 pandemic: a systematic review and meta-analysis, Glob. Health 16 (2020) 57, https://doi.org/ 10.1186/s12992-020-00589-w.
- [30] F. Khademian, S. Delavari, Z. Koohjani, Z. Khademian, An investigation of depression, anxiety, and stress and its relating factors during COVID-19 pandemic in Iran, BMC Publ. Health 21 (2021) 275, https://doi.org/10.1186/s12889-021-10329-3.
- [31] J. Turna, J. Zhang, N. Lamberti, B. Patterson, W. Simpson, A.P. Francisco, C.G. Bergmann, M. Van Ameringen, Anxiety, depression and stress during the COVID-19 pandemic: results from a cross-sectional survey, J. Psychiatr. Res. 137 (2021) 96–103, https://doi.org/10.1016/j.jpsychires.2021.02.059.
- [32] K. Watkins-Martin, M. Orri, M.-H. Pennestri, N. Castellanos-Ryan, S. Larose, J.-P. Gouin, I. Ouellet-Morin, N. Chadi, F. Philippe, M. Boivin, R.E. Tremblay, S. Côté, M.-C. Geoffroy, Depression and anxiety symptoms in young adults before and during the COVID-19 pandemic: evidence from a Canadian populationbased cohort, Ann. Gen. Psychiatr. 20 (2021) 42, https://doi.org/10.1186/s12991-021-00362-2.
- [33] A.J. Rodríguez-Hidalgo, Y. Pantaleón, I. Dios, D. Falla, Fear of COVID-19, stress, and anxiety in university undergraduate students: a predictive model for depression, Front. Psychol. 11 (2020), https://doi.org/10.3389/fpsyg.2020.591797.
- [34] E. Humer, T. Probst, J. Wagner-Skacel, C. Pieh, Association of health behaviors with mental health problems in more than 7000 adolescents during COVID-19, Int. J. Environ. Res. Publ. Health 19 (2022) 9072, https://doi.org/10.3390/ijerph19159072.
- [35] O. Galindo-Vázquez, M. Ramírez-Orozco, R. Costas-Muñiz, L.A. Mendoza-Contreras, G. Calderillo-Ruíz, A. Meneses-García, Symptoms of anxiety and depression and self-care behaviors during the COVID-19 pandemic in the general population, Gac. México. 156 (2020), https://doi.org/10.24875/GMM.M20000399.
- [36] Y. Hernández-Díaz, A.D. Genis-Mendoza, M.Á. Ramos-Méndez, I.E. Juárez-Rojop, C.A. Tovilla-Zárate, T.B. González-Castro, M.L. López-Narváez, H. Nicolini, Mental health impact of the COVID-19 pandemic on Mexican population: a systematic review, Int. J. Environ. Res. Publ. Health 19 (2022) 6953, https://doi. org/10.3390/ijerph19116953.
- [37] A. Karen Limón-Vázquez, G. Guillén-Ruiz, E. Virginia Herrera-Huerta, The social isolation triggered by COVID-19: effects on mental health and education in Mexico, in: Heal. Acad. Achiev. - New Find., IntechOpen, 2021, https://doi.org/10.5772/intechopen.93886.
- [38] J.H. Cohen, N.D. Mata-Sánchez, Challenges, inequalities and COVID-19: examples from indigenous Oaxaca, Mexico, Glob, Publ. Health 16 (2021) 639–649, https://doi.org/10.1080/17441692.2020.1868548.
- [39] G. Terán-Pérez, A. Portillo-Vásquez, Y. Arana-Lechuga, O. Sánchez-Escandón, R. Mercadillo-Caballero, R.O. González-Robles, J. Velázquez-Moctezuma, Sleep and mental health disturbances due to social isolation during the COVID-19 pandemic in Mexico, Int. J. Environ. Res. Publ. Health 18 (2021) 2804, https://doi. org/10.3390/ijerph18062804.
- [40] W. Kawohl, C. Nordt, COVID-19, unemployment, and suicide, Lancet Psychiatr. 7 (2020) 389-390, https://doi.org/10.1016/S2215-0366(20)30141-3.
- [41] M.A. Mamun, I. Ullah, COVID-19 suicides in Pakistan, dying off not COVID-19 fear but poverty? The forthcoming economic challenges for a developing country, Brain Behav. Immun. 87 (2020) 163–166, https://doi.org/10.1016/j.bbi.2020.05.028.
- [42] E. Baltazar-Gaytan, P. Aguilar-Alonso, E. Brambila, H. Tendilla-Beltran, R.A. Vázquez-Roque, J.C. Morales-Medina, N. Maceda-Mártinez, C. Castro-Flores, M. Susano-Pompeyo, L. Garcés-Ramírez, F. de la Cruz, F. García-Dolores, G. Flores, Increased cell number with reduced nitric oxide level and augmented superoxide dismutase activity in the anterior-pituitary region of young suicide completers, J. Chem. Neuroanat. 96 (2019) 7–15, https://doi.org/10.1016/j. jchemneu.2018.11.002.
- [43] A.D. Genis-Mendoza, D.M. Dionisio-García, T.B. Gonzalez-Castro, C.A. Tovilla-Zaráte, I.E. Juárez-Rojop, M.L. López-Narváez, R.G. Castillo-Avila, H. Nicolini, Increased levels of cortisol in individuals with suicide attempt and its relation with the number of suicide attempts and depression, Front. Psychiatr. 13 (2022), https://doi.org/10.3389/fpsyt.2022.912021.
- [44] S. Awan, M.N. Diwan, A. Aamir, Z. Allahuddin, M. Irfan, A. Carano, F. Vellante, A. Ventriglio, M. Fornaro, A. Valchera, M. Pettorruso, G. Martinotti, M. Di Giannantonio, I. Ullah, D. De Berardis, Suicide in healthcare workers: determinants, challenges, and the impact of COVID-19, Front. Psychiatr. 12 (2022), https://doi.org/10.3389/fpsyt.2021.792925.
- [45] M. Walton, E. Murray, M.D. Christian, Mental health care for medical staff and affiliated healthcare workers during the COVID-19 pandemic, Eur. Hear. J. Acute Cardiovasc. Care. 9 (2020) 241–247, https://doi.org/10.1177/2048872620922795.
- [46] M.S. Spoorthy, S.K. Pratapa, S. Mahant, Mental health problems faced by healthcare workers due to the COVID-19 pandemic–A review, Asian J. Psychiatr. 51 (2020), 102119, https://doi.org/10.1016/j.ajp.2020.102119.
- [47] R. Robles, E. Rodríguez, H. Vega-Ramírez, D. Álvarez-Icaza, E. Madrigal, S. Durand, S. Morales-Chainé, C. Astudillo, J. Real-Ramírez, M.-E. Medina-Mora,
- C. Becerra, R. Escamilla, N. Alcocer-Castillejos, L. Ascencio, D. Díaz, H. González, E. Barrón-Velázquez, A. Fresán, L. Rodríguez-Bores, J.-M. Quijada-Gaytán,

G. Zabicky, D. Tejadilla-Orozco, J.-J. González-Olvera, G. Reyes-Terán, Mental health problems among healthcare workers involved with the COVID-19 outbreak, Braz. J. Psych. 43 (2021) 494–503, https://doi.org/10.1590/1516-4446-2020-1346.

- [48] R. Robles, S. Morales-Chainé, A. Bosch, C. Astudillo-García, M. Feria, S. Infante, N. Alcocer-Castillejos, L. Ascencio, J. Real-Ramírez, D. Díaz, H.F. Gómez-Estrada, C. Becerra, R. Escamilla, A. López-Montoya, A. Beristain-Aguirre, H. Vega, D. Álvarez-Icaza, E. Rodríguez, S. Durand, A. Fresán, M.-E. Medina-Mora, C. Fernández-Cáceres, E.Á. Madrigal de León, Mental health problems among COVID-19 frontline healthcare workers and the other country-level epidemics: the case of Mexico, Int. J. Environ. Res. Publ. Health 19 (2021) 421, https://doi.org/10.3390/ijerph19010421.
- [49] R. Tandon, COVID-19 and suicide: just the facts. Key learnings and guidance for action, Asian J. Psychiatr. 60 (2021), 102695, https://doi.org/10.1016/j. ajp.2021.102695.
- [50] A.M. Kim, The impact of the COVID-19 pandemic on suicides: a population study, Psychiatr. Res. 314 (2022), 114663, https://doi.org/10.1016/j. psychres.2022.114663.
- [51] R.S. McIntyre, L.M. Lui, J.D. Rosenblat, R. Ho, H. Gill, R.B. Mansur, K. Teopiz, Y. Liao, C. Lu, M. Subramaniapillai, F. Nasri, Y. Lee, Suicide reduction in Canada during the COVID-19 pandemic: lessons informing national prevention strategies for suicide reduction, J. R. Soc. Med. 114 (2021) 473–479, https://doi.org/ 10.1177/01410768211043186.
- [52] A. Suhail, K.A. Dar, N. Iqbal, COVID-19 related fear and mental health in Indian sample: the buffering effect of support system, Curr. Psychol. 41 (2022) 480–491, https://doi.org/10.1007/s12144-021-01694-8.
- [53] D.D. Dsouza, S. Quadros, Z.J. Hyderabadwala, M.A. Mamun, Aggregated COVID-19 suicide incidences in India: fear of COVID-19 infection is the prominent causative factor, Psychiatr. Res. 290 (2020), 113145, https://doi.org/10.1016/j.psychres.2020.113145.
- [54] C. Rodríguez-Hernández, O. Medrano-Espinosa, A. Hernández-Sánchez, Salud mental de los mexicanos durante la pandemia de COVID-19, Gac. México. 157 (2021), https://doi.org/10.24875/GMM.20000612.
- [55] A.S. Preker, D. Cotlear, S. Kwon, R. Atun, C. Avila, Universal health care in middle-income countries: lessons from four countries, J. Glob. Health. 11 (2021), 16004, https://doi.org/10.7189/jogh.11.16004.
- [56] J. Bantjes, V. Iemmi, E. Coast, K. Channer, T. Leone, D. McDaid, A. Palfreyman, B. Stephens, C. Lund, Poverty and suicide research in low- and middle-income countries: systematic mapping of literature published in English and a proposed research agenda, Glob. Ment. Heal. 3 (2016) e32, https://doi.org/10.1017/ gmh.2016.27.
- [57] B.B. İnanç, Suicide cause and method from 2009-2017 in Turkey, Iran, J. Public Health (2021), https://doi.org/10.18502/ijph.v50i7.6628.
- [58] A.L. Romero-Pimentel, R.C. Mendoza-Morales, A. Fresan, F. Garcia-Dolores, E.E. Gonzalez-Saenz, M.E. Morales-Marin, H. Nicolini, G. Borges, Demographic and clinical characteristics of completed suicides in Mexico city 2014–2015, Front. Psychiatr. 9 (2018), https://doi.org/10.3389/fpsyt.2018.00402.
- [59] S.Y. Arafat, R. Kabir, Suicide prevention strategies: which one to consider?, South east asia, J. Public Health 7 (2017) 1–5, https://doi.org/10.3329/seajph. v7i1.34671.
- [60] M. Taquet, S. Luciano, J.R. Geddes, P.J. Harrison, Bidirectional associations between COVID-19 and psychiatric disorder: retrospective cohort studies of 62 354 COVID-19 cases in the USA, Lancet Psychiatr. 8 (2021) 130–140, https://doi.org/10.1016/S2215-0366(20)30462-4.
- [61] H. Yang, W. Chen, Y. Hu, Y. Chen, Y. Zeng, Y. Sun, Z. Ying, J. He, Y. Qu, D. Lu, F. Fang, U.A. Valdimarsdóttir, H. Song, Pre-pandemic psychiatric disorders and risk of COVID-19: a UK Biobank cohort analysis, Lancet Heal. Longev. 1 (2020) e69, https://doi.org/10.1016/S2666-7568(20)30013-1. -e79.
- [62] B. Vai, M.G. Mazza, C. Delli Colli, M. Foiselle, B. Allen, F. Benedetti, A. Borsini, M. Casanova Dias, R. Tamouza, M. Leboyer, M.E. Benros, I. Branchi, P. Fusar-Poli, L.J. De Picker, Mental disorders and risk of COVID-19-related mortality, hospitalisation, and intensive care unit admission: a systematic review and metaanalysis, Lancet Psychiatr. 8 (2021) 797–812, https://doi.org/10.1016/S2215-0366(21)00232-7.
- [63] S.W. Lee, J.M. Yang, S.Y. Moon, I.K. Yoo, E.K. Ha, S.Y. Kim, U.M. Park, S. Choi, S.-H. Lee, Y.M. Ahn, J.-M. Kim, H.Y. Koh, D.K. Yon, Association between mental illness and COVID-19 susceptibility and clinical outcomes in South Korea: a nationwide cohort study, Lancet Psychiatr. 7 (2020) 1025–1031, https://doi.org/ 10.1016/S2215-0366(20)30421-1.
- [64] M. Canal-Rivero, R. Catalán-Barragán, A. Rubio-García, N. Garrido-Torres, B. Crespo-Facorro, M. Ruiz-Veguilla, Lower risk of SARS-CoV2 infection in individuals with severe mental disorders on antipsychotic treatment: a retrospective epidemiological study in a representative Spanish population, Schizophr. Res. 229 (2021) 53–54, https://doi.org/10.1016/j.schres.2021.02.002.
- [65] H. Tendilla-Beltrán, G. Flores, Due to their anti-inflammatory, antioxidant and neurotrophic properties, second-generation antipsychotics are suitable in patients with schizophrenia and COVID-19, Gen. Hosp. Psychiatr. (2021), https://doi.org/10.1016/j.genhosppsych.2021.05.005.
- [66] N. Hoertel, M. Sánchez-Rico, R. Vernet, N. Beeker, A.-S. Jannot, A. Neuraz, E. Salamanca, N. Paris, C. Daniel, A. Gramfort, G. Lemaitre, M. Bernaux, A. Bellamine, C. Lemogne, G. Airagnes, A. Burgun, F. Limosin, Association between antidepressant use and reduced risk of intubation or death in hospitalized patients with COVID-19: results from an observational study, Mol. Psychiatr. 26 (2021) 5199–5212, https://doi.org/10.1038/s41380-021-01021-4.
- [67] E.J. Lenze, C. Mattar, C.F. Zorumski, A. Stevens, J. Schweiger, G.E. Nicol, J.P. Miller, L. Yang, M. Yingling, M.S. Avidan, A.M. Reiersen, Fluvoxamine vs placebo and clinical deterioration in outpatients with symptomatic COVID-19, JAMA 324 (2020) 2292, https://doi.org/10.1001/jama.2020.22760.
- [68] Á.R. Rivas-Ramírez, H. Tendilla-Beltrán, L.E. Gómez-Mendoza, G. Loaiza, G. Flores, Patients with schizophrenia have decreased COVID-19 prevalence among hospitalized patients with psychiatric and neurological diseases: a retrospective analysis in Mexican population, Int. J. Clin. Pract. (2021), https://doi.org/ 10.1111/ijcp.14528.