Mortality risk during heat waves in the summer 2013-2014 in 18 provinces of Argentina: Ecological study

Risco de mortalidade durante ondas de calor no verão 2013-2014 em 18 províncias da Argentina: Estudo ecológico

Francisco Chesini (https://orcid.org/0000-0001-6555-458X) [1]
Natalia Herrera (https://orcid.org/0000-0003-4123-0075) [2]
Maria de los Milagros Skansi (https://orcid.org/0000-0002-0870-5609) [2]
Carolina González Morinigo (https://orcid.org/0000-0002-8002-8518) [3]
Silvia Fontán (https://orcid.org/0000-0003-2205-1063) [4]
Francisco Savoy (https://orcid.org/0000-0002-9696-8045) [5]
Ernesto de Titto (https://orcid.org/0000-0002-4375-3278) [1]

Abstract *Increased frequency of heat waves (HWs) is one of the prominent consequences of climate change. Its impact on human health has been mostly reported in the northern hemisphere but has been poorly studied in the southern hemisphere. The aim of this study was to analyze the effects of the HWs waves occurred in the warm season 2013-14 on mortality in the center-north region of Argentina, where 22 million people live. It was carried out an observational study of ecological-type contrasting the mortality occurred during the HWs of the summer 2013-14 with the mortality in the summers 2010-11 to 2012-13, free from HWs. The mortality was analyzed according to the following variables: place of residence, age, sex and cause of death. During the HWs of the summer 2013-14, 1877 (RR=1.23, 95%CI 1.20-1.28) deaths in excess were registered. Moreover, the death risk significantly increased in 13 of the 18 provinces analyzed. The mortality rates by sex revealed heterogeneous behaviour regarding both the time and spatial scale. The death risk increased with age; it was particularly significant in four provinces for the 60-79 years group and in six provinces in people of 80 years and over. The death causes that showed significantly increments were respiratory, cardiovascular, renal diseases and diabetes.*

Key words *Mortality, Heatwave, Climate change, Environmental health, Death risk*

Resumo *O aumento da frequência das ondas de calor (OsC) é uma das consequências proeminentes das alterações climáticas. O seu impacto na saúde humana tem sido relatado principalmente no hemisfério norte, mas tem sido mal estudado no hemisfério sul. O objetivo deste estudo foi analisar os efeitos das OsC ocorridas no verão de 2013-14 sobre a mortalidade na região centro-norte da Argentina, onde 22 milhões de pessoas vivem. Foi realizado um estudo observacional de tipo ecológico que contrasta a mortalidade ocorrida durante as OsC do verão 2013-14 com a mortalidade nos verões 2010-11 a 2012-13. A mortalidade foi analisada de acordo com local de residência, idade, sexo e causa de morte. Durante as OsC do verão de 2013-14, registaram-se 1.877 (RR=1.23, 95%IC 1.20-1.28) mortes em excesso. O risco de morte (RM) aumentou significativamente em 13 das 18 províncias analisadas. As taxas de mortalidade por sexo revelaram um comportamento heterogêneo tanto no tempo como na escala espacial. O RM foi aumentado com a idade; este aumento foi particularmente significativo em quatro províncias para o grupo de 60-79 anos e em seis províncias em pessoas com mais de 80 anos. As causas de morte que mostraram significativamente incrementos foram: doenças respiratórias, cardiovasculares, renais e diabetes.*

Palavras-chave *Mortalidade, Onda de calor, Mudanças climáticas, Saúde ambiental, Risco de morte*

[1] Salud Ambiental, Ministerio de Salud de la Nación. Av. 9 de Julio 1925. C1073ABA Ciudad Autónoma de Buenos Aires Argentina. ehdetitto@gmail.com
[2] Dirección Central de Monitoreo del Clima, Dirección Nacional de Ciencia e Innovación en Productos y Servicios. Ciudad Autónoma de Buenos Aires Argentina.
[3] Dirección de Servicios Sectoriales, Dirección Nacional de Pronósticos y Servicios para la Sociedad, Servicio Meteorológico Nacional. Ciudad Autónoma de Buenos Aires Argentina.
[4] Departamento de Ciencias de la Salud, Universidad Nacional de La Matanza. Provincia de Buenos Aires Argentina.
[5] Facultad de Ciencias de la Salud, Universidad Nacional de Entre Ríos. Provincia de Entre Ríos Argentina.

Introduction

The health sector is paying increasing attention to the close relationship between climate change and human health. Thus, in 2008, the World Health Assembly recognized climate change as an environmental determinant of health[1] and in 2009 the Ministers of Health from MERCOSUR established an Action Strategy to protect human health from climate change effects[2].

Among the manifestations of climate change with significant impact on human and natural systems stands out an increasing duration and frequency of heat waves (HWs)[3], which been documented on several occasions. For example: the HW that occurred in Chicago in July 1995 caused a 147% increase in deaths (during the most intense heat – July 14 through 20 –, there were 485 heat-related deaths and 739 excess deaths)[4]; in Europe in 2003, the HW death rates increased 4 to 5 times causing around additional 70.000 deaths[5,6]; and in 2010 the Russian Federation had a HW that lasted 44 days and caused 10.000 excess deaths only in Moscow[7].

Several studies showed the increase in both hospitalizations and mortality during HW days, with risk increases for cardiovascular, cerebrovascular, respiratory and kidney diseases[8-10]. Although all individuals are potentially exposed to a HW, the risk levels can be modified by other factors such as living in large cities, socioeconomic conditions, gender, behaviour and even the consumption of medicines[3,11]. The most vulnerable groups are the elderly, the children, the chronically ill and people working outdoors[3,8].

Since HW lacks of an internationally agreed definition[11,12], the National Meteorological Service of Argentina (NMSA) defines HW as the period in which the maximum and minimum temperatures equal or exceed for at least 3 consecutive days the 90th percentile, calculated from daily data during the months from October to March of the period 1961-2010[13]. In line with the evolution of global warming, in this period the frequency of HW has increased in the north and east of the country, showing a pronounced decadal variability with the highest numbers in the decade 2001-2010[14,15].

The summer season 2013-2014 was particularly hot. Starting on the month of December 2013, the persistence record for days with extremely high temperatures was exceeded, mainly in the central and northern part of the national territory.

Intraseasonal variability can explain on average at least 32% of summer temperature variance. Moreover, 73% of the HWs in subtropical South America develop in association with an active South Atlantic Convergence Zone (SACZ)[16]. The development of the anticyclonic circulation over subtropical South America appears to be strengthened by the subsidence conditions promoted by the active SACZ, which result in temperature rise in the region under relatively dry conditions. As result of these land and atmospheric conditions, a high coupling (water-limited) regime was imposed, promoting the re-amplification of hot spells that resulted in mega HW episodes[17]. Several studies analyzed strong and long HWs episodes occurred in the austral summer season 2013-2014 over Southern South America[13,17-19].

Some studies have been carried out in Argentina on the relationship between meteorological conditions and health. In one of them it was investigated the short-term effects of temperature and atmospheric carbon monoxide changes in daily mortality in Buenos Aires City (CABA)[20]. Other study analyzed the relationship between temperature and general mortality in CABA and Rosario, the two most populated cities in the country, finding that the relationship follows a "U" form with increases in deaths at both extremes of temperature (cold and warm)[21]. Recently, some of us analyzed mortality in CABA during HWs, observing a significant increase in the risk of dying, with predominant impact in the mortality in women and elder age[22].

Given the increasing frequency of HWs, it is necessary to identify the local epidemiological profile and their sanitary burden in order to design proper health promotion strategies to alleviate their impact on the population. For this reason, the aim of this study was to analyze the effects of the HWs occurred in the warm season 2013-14 on mortality in the center-north region of Argentina, where 22 million people live.

Materials and methods

This is an ecological type observational study and the units of analysis are the population of each jurisdiction (17 Provinces and CABA, which for practical purposes was also considered a province); as presented in Figure 1.

Ciência & Saúde Coletiva, 27(5):2071-2086, 2022

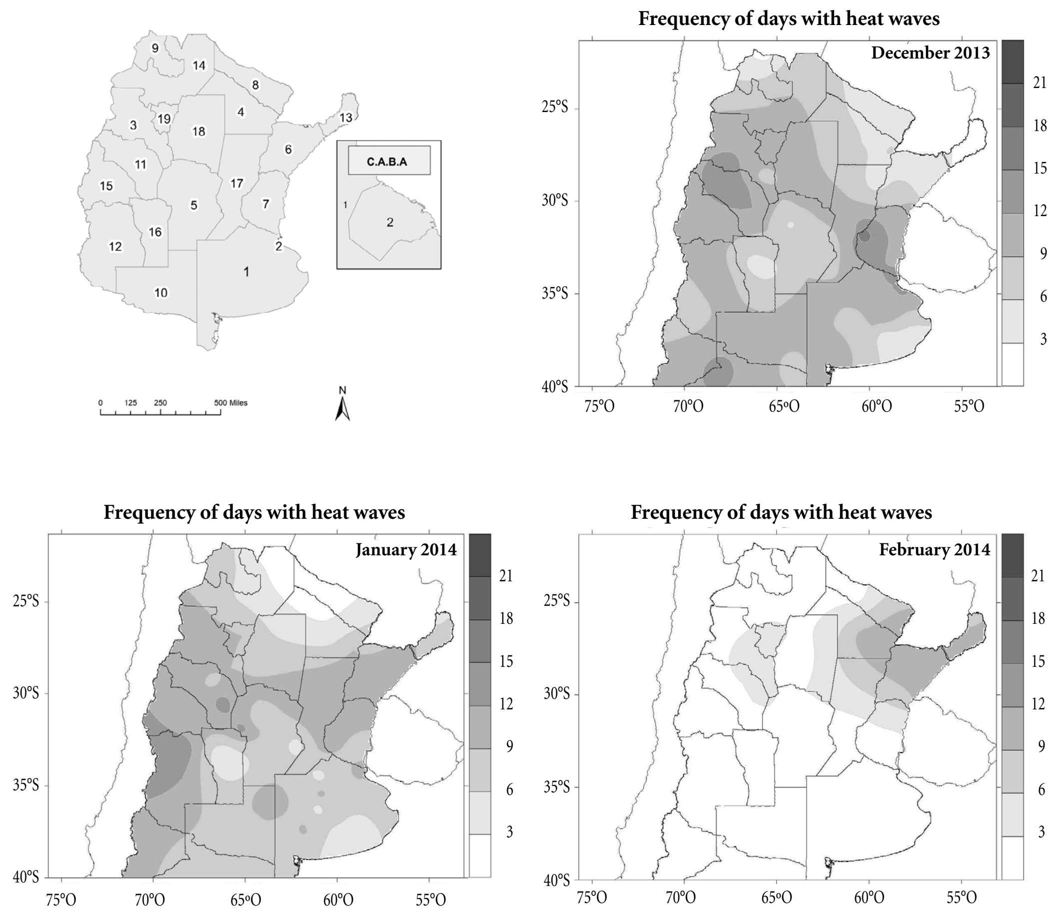

Figure 1. Geographical distribution and number of days with high temperature.

Provinces represented by a number on the extreme left map are: 1. Buenos Aires (excluded from this study - see Materials and Methods), 2. Buenos Aires City (CABA), 3. Catamarca, 4. Chaco, 5. Córdoba, 6. Corrientes, 7. Entre Ríos, 8. Formosa, 9. Jujuy, 10. La Pampa, 11. La Rioja, 12. Mendoza, 13. Misiones, 14. Salta, 15. San Juan, 16. San Luis, 17. Santa Fe, 18. Santiago del Estero, 19. Tucumán.

Source: Authors, with data provided by the National Metereological Service.

Study area

The geographic scope of the present study was based on previous studies that analyzed the long-term variability of HWs[13,15]. Thus, we revised data from the 57 meteorological stations distributed on the provinces located north of the 40th parallel south.

Argentina is a highly urbanized country; according to the last national census (2010) 91% of the population lives in cities[23]. In Argentina the life expectancy is 75.3 years (78.8 for women and 72.8 for men)[24]. Since the 1970s, a population aging process has been observed: people over 65 years old represented 7.0% of the national population in 1970 and 10.2% in 2010.

The Patagonian provinces were excluded from this study; since the HWs that can be recorded there are not of sanitary relevance because the threshold values of the minimum temperature are too low. The province of Buenos Aires was also excluded from this study since for administrative reasons mortality cases in this province are charged monthly and there is no way to get access to the actual date of the deaths from secondary data. Moreover, given its extent (approximately 307.000 km²) HWs never cover the whole province.

Analysis unit

The units of analysis are delimited from the political division. Data collection units are composed of the individual cases of death that occurred during the HWs. These individual cases were integrated into units of analysis called provinces, which include the deaths that occurred in each of the 18 provinces (Figure 1).

Analysis

We first identified HWs that occurred in the summer 2013-2014 in the study area, based on the criteria defined by the NMSA[13]. Once the HWs were identified, maps were drawn indicating the number of days with HW, to determine the areas affected by the events and the start and end dates of each HW for each jurisdiction. Then, a spatial overlay analysis was carried out in a Geographic Information System (GIS) to be able to indicate the affected departments in each province and to undertake an individualized analysis of them. The layer in "shape" format with the division by departments was provided by the National Geographic Institute.

To analyze mortality we selected natural death cases registered in the categories included between codes A00 and R99 according to the 10th Revision of the International Classification of Diseases (ICD-10), excluding external causes of death[8,25], from the data basis provided by the National Ministry of Health.

The explicative variable (presence of HW) and the outcome variable (mortality) were studied simultaneously[26]. The study compared the daily mortality that occurred during each HW in the warm semester 2013-2014 (October 2013 to March 2014) with the average of the daily mortality that occurred during the same dates on the three previous warm seasons (2010-2011 to 2012-2013). The difference between the numbers of deaths during both periods was taken as excessive deaths. It must be noted that on selecting the reference period we required that they lacked HWs so that the comparisons were in the same population and social environment[27]. The number of deaths according to the cause of death, age at the time of death, sex and place of residence were taken as response variables.

We calculated the frequencies of cases and rates by age group, sex and cause of death, for HWs and for the reference period. In addition, the relative risks (RR) were calculated as the ratio of mortality rates during each HW and mortality rates in the absence of HW (average of the previous three years). It was also calculated its confidence interval of 95% (95%CI).

Mortality by age was grouped into five categories: 0 to 19; 20 to 39; 40 to 59; 60 to 79 and 80 and more years, as proposed by the specialized bibliography[28].

Information sources

The information analyzed comes from secondary sources. Statistical data on mortality from 2010 to 2014 were provided by the Direction of Health Statistics and Information of the National Ministry of Health. Population data were obtained from the National Institute of Statistics and Census and the meteorological information (maximal and minimal daily temperatures to build the HW dichotomic variable, following NMSA definition) from 1961 to 2010 for the reference period and from the warm season 2013-14 for the study was provided by the NMSA.

Tools to process information were: "Epiinfo" for Windows version 3.5.3, "ArcGis" version 9.3.1 and Surfer 7 for making maps and package Microsoft Office 2007.

Results

Analysis of heat waves in summer 2013-2014

This research analyzed meteorological data from Argentina during the warm semester for the southern hemisphere (October to March) and focused the study in the months of December 2013 and January-February 2014 since there were no HWs in October and November 2013 and March 2014.

The temperature during the summer 2013-2014 was especially high in practically the whole country, as it can be seen on Figure 1, where the number of days within each month with both maximum and minimum temperatures simultaneously exceeding 90th percentile is presented.

The HWs registered in each of the provinces with their start and end dates, their duration and comparison with the HWs that occurred in the 1961-2010 period are presented in Table 1. It is indicated when the HW was higher than the 80th, 85th, 90th or 95th percentile in *duration*, *maximum* *temperature average* (T. max) and/or *minimum temperature average* (T. min). For example: Entre Rios had a 16 days long HW in December 2013; this duration was greater than 95th percentile, a T. max greater than 90th percentile and a T. min higher than the 80th percentile when compared

Table 1. Heat waves in all provinces and comparison with the historical (1961-2010) heat waves.

<table>
<tr><th colspan="17">Dec-13</th><th colspan="2">Jan-14</th><th>duration</th><th colspan="3">vs 1961-2010*</th></tr>
<tr><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th><th>31</th><th>1</th><th>2</th><th>(days)</th><th>duration</th><th>T. max.</th><th>T. min.</th></tr>
<tr><td colspan="16">Entre Ríos</td><td colspan="3"></td><td>16</td><td>≥P95</td><td>≥P90</td><td>≥P80</td></tr>
<tr><td colspan="2"></td><td colspan="14">Santa Fe</td><td colspan="3"></td><td>14</td><td>≥P95</td><td>≥P95</td><td>≥P80</td></tr>
<tr><td colspan="7"></td><td colspan="9">CABA</td><td colspan="3"></td><td>9</td><td>≥P95</td><td>≥P90</td><td>≥P85</td></tr>
<tr><td colspan="5"></td><td colspan="5">La Pampa</td><td colspan="9"></td><td>5</td><td>≥P95</td><td>≥P80</td><td>≥P90</td></tr>
<tr><td colspan="6"></td><td colspan="5">San Luis</td><td colspan="8"></td><td>5</td><td>≥P90</td><td></td><td>≥P90</td></tr>
<tr><td colspan="6"></td><td colspan="5">Mendoza</td><td colspan="8"></td><td>5</td><td>≥P85</td><td></td><td>≥P95</td></tr>
<tr><td colspan="6"></td><td colspan="5">San Juan</td><td colspan="8"></td><td>5</td><td>≥P90</td><td></td><td>≥P95</td></tr>
<tr><td colspan="6"></td><td colspan="7">Córdoba</td><td colspan="6"></td><td>7</td><td>≥P95</td><td>≥P80</td><td>≥P80</td></tr>
<tr><td colspan="7"></td><td colspan="7">La Rioja</td><td colspan="5"></td><td>7</td><td>≥P95</td><td>≥P95</td><td>≥P95</td></tr>
<tr><td colspan="7"></td><td colspan="7">Tucumán</td><td colspan="5"></td><td>7</td><td>≥P95</td><td>≥P80</td><td>≥P85</td></tr>
<tr><td colspan="8"></td><td colspan="6">Stgo. del Estero</td><td colspan="5"></td><td>6</td><td></td><td>≥P95</td><td></td></tr>
<tr><td colspan="9"></td><td colspan="5">Catamarca</td><td colspan="5"></td><td>5</td><td>≥P90</td><td>≥P85</td><td></td></tr>
<tr><td colspan="11"></td><td colspan="6">Corrientes</td><td colspan="2"></td><td>6</td><td>≥P90</td><td>≥P85</td><td>≥P90</td></tr>
<tr><td colspan="11"></td><td colspan="6">Chaco</td><td colspan="2"></td><td>6</td><td></td><td></td><td></td></tr>
<tr><td colspan="11"></td><td colspan="6">Formosa</td><td colspan="2"></td><td>6</td><td>≥P80</td><td></td><td></td></tr>
<tr><td colspan="11"></td><td colspan="6">Jujuy</td><td colspan="2"></td><td>6</td><td>≥P95</td><td>≥P95</td><td></td></tr>
<tr><td colspan="12"></td><td colspan="7">Salta</td><td>7</td><td>≥P95</td><td>≥P95</td><td>≥P95</td></tr>
<tr><th colspan="19">Jan-14</th><th></th><th colspan="3"></th></tr>
<tr><th colspan="7"></th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>duration</th><th>duration</th><th>T. max.</th><th>T. min.</th></tr>
<tr><td colspan="7"></td><td colspan="9">Mendoza</td><td colspan="3"></td><td>9</td><td>≥P85</td><td>≥P95</td><td>≥P95</td></tr>
<tr><td colspan="8"></td><td colspan="10">San Luis</td><td></td><td>10</td><td>≥P95</td><td>≥P85</td><td>≥P80</td></tr>
<tr><td colspan="8"></td><td colspan="10">Córdoba</td><td></td><td>10</td><td>≥P95</td><td></td><td>≥P90</td></tr>
<tr><td colspan="9"></td><td colspan="6">La Pampa</td><td colspan="4"></td><td>6</td><td>≥P95</td><td>≥P95</td><td>≥P95</td></tr>
<tr><td colspan="9"></td><td colspan="4">CABA</td><td colspan="6"></td><td>4</td><td>≥P80</td><td>≥P80</td><td>≥P85</td></tr>
<tr><td colspan="9"></td><td colspan="9">Santa Fe</td><td></td><td>9</td><td>≥P95</td><td>≥P85</td><td>≥P95</td></tr>
<tr><td colspan="9"></td><td colspan="9">Entre Ríos</td><td></td><td>9</td><td>≥P90</td><td>≥P90</td><td>≥P95</td></tr>
<tr><td colspan="11"></td><td colspan="7">Corrientes</td><td></td><td>7</td><td>≥P95</td><td>≥P80</td><td>≥P95</td></tr>
<tr><td colspan="12"></td><td colspan="7">Misiones</td><td>7</td><td>≥P95</td><td></td><td></td></tr>
<tr><td colspan="15"></td><td colspan="4">Chaco</td><td>4</td><td></td><td></td><td></td></tr>
<tr><td colspan="15"></td><td colspan="4">Formosa</td><td>4</td><td>≥P80</td><td></td><td></td></tr>
<tr><td colspan="14"></td><td colspan="4">Salta</td><td></td><td>4</td><td>≥P95</td><td></td><td>≥P90</td></tr>
<tr><td colspan="14"></td><td colspan="4">Tucuman</td><td></td><td>4</td><td>≥P85</td><td>≥P80</td><td>≥P95</td></tr>
<tr><td colspan="14"></td><td colspan="4">La Rioja</td><td></td><td>4</td><td></td><td>≥P95</td><td>≥P95</td></tr>
<tr><td colspan="15"></td><td colspan="3">Catamarca</td><td></td><td>3</td><td></td><td>≥P95</td><td>≥P95</td></tr>
<tr><td colspan="15"></td><td colspan="3">Jujuy</td><td></td><td>3</td><td></td><td></td><td>≥P95</td></tr>
<tr><th colspan="7">Jan-14</th><th colspan="12">Feb-14</th><th></th><th colspan="3"></th></tr>
<tr><th colspan="5"></th><th>30</th><th>31</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>duration</th><th>duration</th><th>T. max.</th><th>T. mín.</th></tr>
<tr><td colspan="5"></td><td colspan="13">Corrientes</td><td></td><td>13</td><td>≥P95</td><td>≥P85</td><td></td></tr>
<tr><td colspan="6"></td><td colspan="12">Chaco</td><td></td><td>12</td><td>≥P95</td><td>≥P95</td><td></td></tr>
<tr><td colspan="6"></td><td colspan="12">Formosa</td><td></td><td>11</td><td>≥P95</td><td></td><td></td></tr>
<tr><td colspan="6"></td><td colspan="13">Misiones</td><td>11</td><td>≥P95</td><td>≥P95</td><td>≥P95</td></tr>
</table>

*Statistical significance of duration, maximal (T.max.) and minimal (T.min.) temperatures as compared with historical values, expressed as the percentile. Only values above 80th percentile are shown, therefore empty spaces refer to non statistically different values.

Source: Authors, with data provided by the National Metereological Service.

to HWs in the 1961-2010 period. In the case of Chaco, the HW had duration of 6 days, and it was not above the 80th percentile in any of the mentioned variables as compared to the HWs in the same province in the 1961-2010 period. The dates presented in the table are indicative since some provinces have more than one meteorological station and registered HWs do not necessarily coincide in the start and end dates. In those cases in which the HW did not affect the whole province, the analysis was carried out for the departments covered by the HW. In addition, when an HW was interrupted for a day but then the phenomenon continued, they were analyzed as a single event.

We thus identified 3 major periods under HWs in the warm semester 2013-14 in Argentina, in all cases extended in areas larger than one province. The HW in December 2013 reached 17 provinces with duration from 5 days in several provinces to 16 days in Entre Ríos. In January 2014 provinces under HWs were 16 although they were to some extent shorter, from 3 to 10 days. Different was the case of the HW in February which extended for 11 to 13 days over 4 northeastern provinces, close to the frontiers with Paraguay and Brazil. In consequence we found 37 provincial events of HWs in the time period studied.

It is interesting to note the different evolution of HWs in December and January. The first wave started in the eastern portion of the country, close to the Atlantic Ocean, then went to the west till the Andes, and later it went north coming back finally to the east. Instead, the second wave started by the Andes, then it traversed the continent to the east in direction to the Atlantic Ocean, north to the frontier with Paraguay and west again to the Andes.

When examining provincial results, we found 20 cases (9 in December, 7 in January and 4 in February) with extreme high (>95th percentile) mean duration, 11 cases (5, 4 and 2 respectively) with extreme high (>95th percentile) mean maximum temperature and 14 cases (4, 9 and 1, respectively) with extreme high (>95th percentile) mean minimum temperature than those historically recorded for HWs.

Provinces suffering the most severe impact of HWs (in terms of duration, maximum and minimum temperatures >P95th percentile, when compared with the 1961-2010 period) were La Rioja and Salta in December, La Pampa and Mendoza in January and Misiones in February.

Analysis of General Mortality

During the HWs that occurred in the summer of 2013-14 there were 8.759 deaths, 1.877 deaths in excess over the reference period for the total of the provinces analyzed (RR=1.23, 95%CI 1.20-1.28). Excess numbers of mortal cases were present in 32 of the 37 provincial events identified; only events in Jujuy, La Pampa and Tucumán in December and Chaco and Formosa in January did not present exceeding mortal cases.

General mortality rates and RR for each province under analysis are presented in Table 2. We found RR significantly increased during at least one HW in 13 out of the 18 provinces. In the provinces where the RR was statistically higher during the HWs than in its absence, the increase in the number of deaths accounted for 1.716 (1.28, 95%CI 1.24-1.33) deaths over those registered in the reference period.

The HW of December 2013 affected 17 provinces, adding up an excess mortality of 1.046 (RR=1.28, 95%CI 1.23-1.34) deaths. The risk of dying was statistically higher in 7 out of the 15 jurisdictions that had increased mortality. The greatest increase in risk was recorded in Santiago del Estero (RR=1.65, 95%CI 1.21-2.26) where the maximum temperature was higher than 95th percentile, followed by CABA (RR=1.48, 95%CI 1.34-1.65) where the duration was very long (≥95th percentile), the average maximum temperature exceeded 90th percentile and the average minimum temperature exceeded 85th percentile (Table 1).

In January, the HW reached 16 jurisdictions, six of which presented significant increases in the risk of dying. The highest increase in mortality was registered in La Rioja (RR=2.3, 95%CI 1.48-3.58) where the event was extreme in temperatures (>95th percentile) but not in duration, followed by Tucumán (RR=1.36, 95%CI 1.12-1.64).

The HW in February, which was extreme in duration (>95th percentile), covered only the northeast of Argentina, with significant increases in the risk of dying in three out of the four provinces affected: Chaco (RR=1.34, 95%CI 1.18-1.53), Misiones (RR=1.25, 95%CI 1.10-1.43) and Corrientes (RR=1.22, 95%CI 1.08-1.39).

Mortality by sex

The specific mortality rates and the RR by sex were calculated for each province and HW and are presented in Table 3. To present a spatial view

Table 2. Provincial mortality rates and Relative Risk of Dying. Argentina, summer 2013-2014.

Month	Province	Mean values 2010-13		2013-2014		Difference in the number of deaths	RR†	IC95%‡
		Cases	General Rates*	Cases	General Rates			
December	CABA	664	21.8	984	32.1	320	1.48	1.34-1.63
	Catamarca	37	9.8	54	14.2	17	1.42	0.93-2.15
	Chaco	78	8.1	100	9.9	22	1.26	0.94-1.69
	Córdoba	567	16.6	724	20.9	157	1.25	1.12-1.39
	Corrientes	60	7.5	72	9.1	12	1.18	0.84-1.66
	Entre Ríos	366	28.9	487	36.8	121	1.30	1.19-1.43
	Formosa	37	6.7	50	8.9	13	1.31	0.86-2.00
	Jujuy	52	7.6	48	7.4	-4	0.89	0.60-1.32
	La Pampa	33	9.9	24	7.2	-9	0.72	0.43-1.22
	La Rioja	32	9.1	50	13.8	18	1.54	0.98-2.40
	Mendoza	164	9.1	212	12.2	48	1.26	1.03-1.54
	Salta	114	9.0	150	11.7	36	1.28	1.04-1.63
	San Juan	52	7.4	75	10.3	23	1.41	0.99-2.00
	San Luis	38	8.4	41	9.2	3	1.05	0.68-1.63
	Santa Fe	817	27.1	1.080	35.1	263	1.30	1.22-1.38
	Santiago del E	63	7.1	106	12.2	43	1.65	1.21-2.26
	Tucumán	145	9.6	108	6.8	-37	0.72	0.56-0.93
	Subtotal	3319	15.1	4365	19.3	1046	1.28	1.23-1.34
January	CABA	294	9.7	345	11.0	51	1.17	1.05-1.31
	Catamarca	23	5.9	32	8.1	9	1.39	0.90-2.14
	Chaco	33	6.1	30	5.2	-3	0.88	0.58-1.33
	Córdoba	756	21.9	894	24.9	138	1.16	1.08-1.24
	Corrientes	143	13.8	180	17.3	37	1.23	0.99-1.54
	Entre Ríos	205	16.0	227	16.9	22	1.08	0.94-1.25
	Formosa	23	6.3	24	6.2	1	1.02	0.63-1.66
	Jujuy	35	5.0	39	5.4	4	1.10	0.76-1.59
	La Pampa	53	15.8	54	15.9	1	1.01	0.74-1.37
	La Rioja	16	4.6	38	10.1	22	2.30	1.48-3.58
	Mendoza	332	18.3	414	22.2	82	1.22	1.10-1.35
	Misiones	98	8.5	103	8.9	5	1.03	0.83-1.27
	Salta	50	3.9	64	5.1	14	1.23	0.93-1.64
	San Luis	80	17.5	94	20.0	14	1.15	0.91-1.44
	Santa Fe	603	19.2	803	25.1	200	1.31	1.22-1.41
	Tucumán	96	6.3	134	9.3	38	1.36	1.12-1.64
	Subtotal	2840	13.2	3475	15.7	635	1.19	1.14-1.25
February	Chaco	204	18.4	280	24.9	76	1.34	1.18-1.53
	Corrientes	221	21.3	276	26.1	55	1.22	1.08-1.39
	Formosa	100	19.2	109	21.2	9	1.07	0.87-1.32
	Misiones	198	17.3	254	22.4	56	1.25	1.10-1.43
	Subtotal	723	19.0	919	23.5	196	1.24	1.12-1.36
Total		6882	30.0	8759	37.1	1877	1.23	1.20-1.28

*Rates per 100.000 inhabitants; †Relative Risk; ‡Confidence Interval 95 %.

Source: Authors, with data provided by the Ministry of Health.

of these results, the RR maps for each of the HWs of summer 2013-2014 are presented in Figure 2.

A heterogeneous behaviour was observed between the provinces and even within the same province during different events. For example, the risk of dying in CABA during the HW of December was significantly high in both women and men (RR=1.58 and RR=1.34 respective-

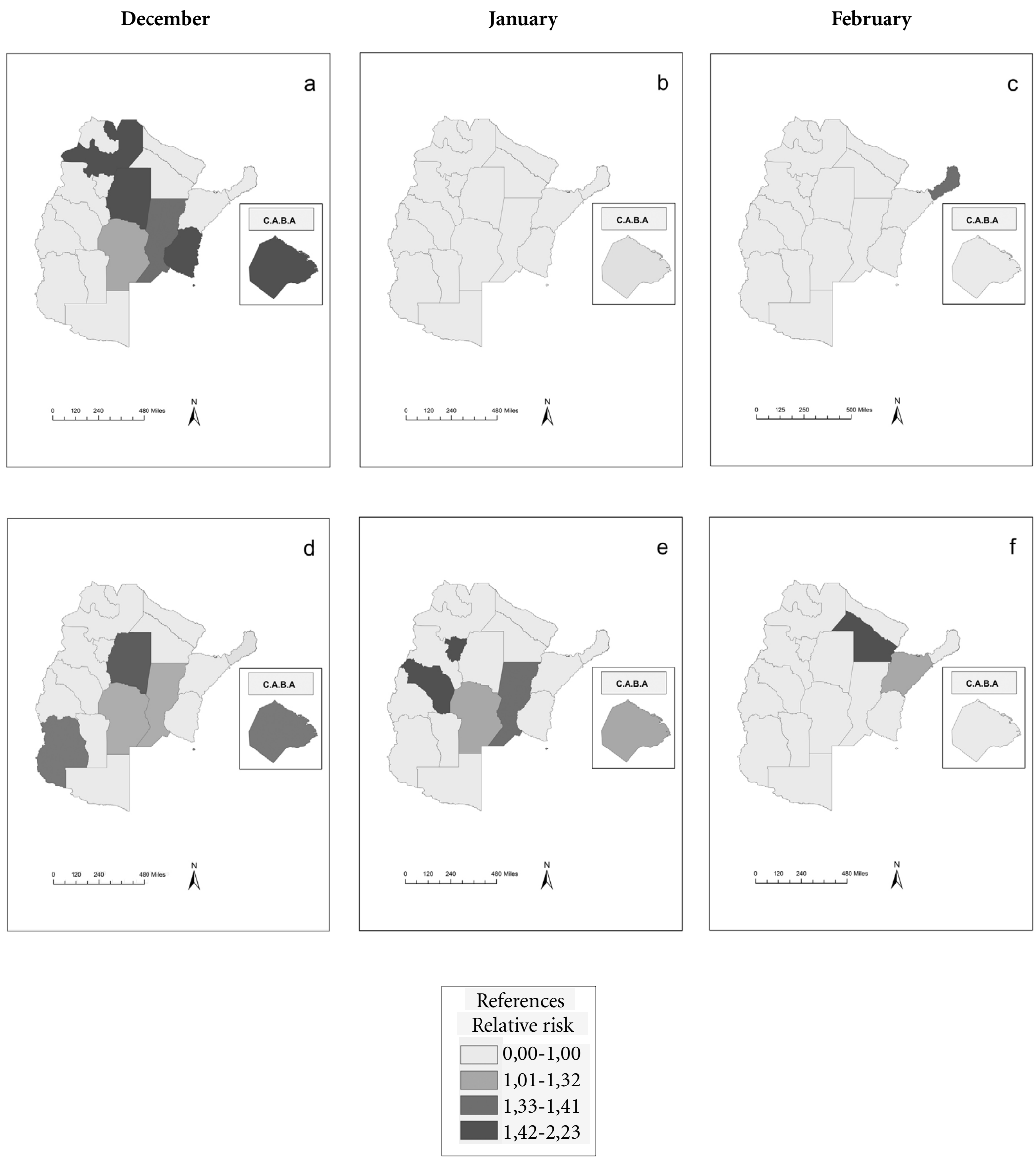

Figure 2. Relative risk maps for women (a, b, c) and men (d, e, f) during heat waves of summer 2013-2014 in Argentina.

Source: Authors, with data provided by the Ministry of Health.

ly), while during the HW of January the increase was only significant in males (RR=1.33). Another general observation was that RRs did not paralleled mortality rates on sex separated calculus.

During the HW of December, the risk of dying for women increased significantly in six provinces with Santiago del Estero presenting the highest value (RR=1.67) followed by CABA (RR=1.58) and Entre Ríos (RR=1.53). During the HW of January the mortality of women did not show significantly increased risk for any of the 16 provinces involved, while in the HW of February, out of the four provinces involved only females from the province of Misiones presented a relative risk significantly increased (RR=1.36).

The risk of dying among males was significantly increased in five provinces during HWs in December, another five in January HW and in

Ciência & Saúde Coletiva, 27(5):2071-2086, 2022

Table 3. Relative risk for sex and age groups during heat waves of summer 2013-2014 in Argentina.

Month	Province	Woman			Men			60-79 years old			over 79 years old		
		RR*	CI95%‡		RR	CI95%		RR	CI95%		RR	CI95%	
December	CABA	1.6	1.39	1.80	1.3	1.15	1.57	1.3	1.09	1.53	1.7	1.47	1.90
	Catamarca	1.3	0.73	2.38	1.5	0.84	2.75	1.0	0.47	2.02	1.8	0.72	4.64
	Chaco	1.5	0.94	2.24	1.1	0.73	1.66	1.3	0.80	1.99	1.4	0.83	2.27
	Córdoba	1.3	1.07	1.46	1.2	1.06	1.45	1.2	0.98	1.40	1.3	1.14	1.58
	Corrientes	1.1	0.65	1.71	1.3	0.82	2.17	1.2	0.73	2.12	1.2	0.69	2.25
	Entre Ríos	1.5	1.27	1.86	1.1	0.90	1.33	1.2	0.97	1.49	1.3	1.09	1.67
	Formosa	1.5	0.81	2.66	1.2	0.64	2.13	1.3	0.64	2.47	1.4	0.58	3.23
	Jujuy	1.0	0.59	1.78	0.8	0.44	1.36	0.9	0.47	1.54	0.8	0.41	1.57
	La Pampa	0.6	0.30	1.35	0.8	0.39	1.70	0.8	0.32	1.83	0.7	0.32	1.51
	La Rioja	1.7	0.89	3.18	1.4	0.75	2.62	2.0	0.97	4.15	1.6	0.73	3.47
	Mendoza	1.2	0.88	1.56	1.4	1.01	1.81	1.1	0.80	1.52	1.3	0.94	1.78
	Salta	1.5	1.03	2.08	1.1	0.80	1.58	0.7	0.46	1.00	1.1	0.67	1.78
	San Juan	1.4	0.83	2.22	1.5	0.88	2.43	1.4	0.81	2.48	1.3	0.72	2.30
	San Luis	1.6	0.84	2.99	0.7	0.36	1.30	1.1	0.57	2.06	1.1	0.51	2.39
	Santa Fe	1.4	1.23	1.59	1.2	1.06	1.37	1.2	1.06	1.41	1.5	1.28	1.69
	Santiago del E	1.7	1.05	2.64	1.6	1.07	2.51	1.5	0.94	2.47	1.5	0.89	2.51
	Tucumán	0.7	0.48	0.99	0.8	0.54	1.08	0.9	0.59	1.27	0.5	0.35	0.84
January	CABA	1.1	0.49	2.28	1.3	1.12	1.58	1.3	0.97	1.70	1.1	0.87	1.33
	Catamarca	1.3	0.50	3.16	1.6	0.75	3.36	1.3	0.57	2.86	1.8	0.72	4.64
	Chaco	0.5	0.12	1.91	1.4	0.80	2.45	0.9	0.44	1.89	1.3	0.57	3.03
	Córdoba	1.1	0.67	1.79	1.2	1.11	1.35	1.1	0.90	1.23	1.3	1.10	1.47
	Corrientes	1.2	0.90	1.71	1.2	0.90	1.65	1.2	0.82	1.63	1.2	0.80	1.68
	Entre Ríos	1.1	0.84	1.49	1.0	0.84	1.42	1.3	0.97	1.75	1.0	0.72	1.30
	Formosa	0.7	0.18	2.82	1.2	0.62	2.22	0.8	0.33	2.16	1.7	0.62	4.85
	Jujuy	1.1	0.28	4.35	1.1	0.65	1.83	1.6	0.80	3.14	0.9	0.40	2.14
	La Pampa	1.0	0.49	1.84	1.1	0.69	1.62	0.9	0.47	1.62	1.2	0.71	2.03
	La Rioja	2.4	0.80	7.14	2.2	1.15	4.34	2.4	0.99	5.70	3.0	0.94	9.73
	Mendoza	1.3	0.78	2.16	1.1	0.97	1.32	1.3	1.06	1.65	1.1	0.89	1.40
	Misiones	0.8	0.59	1.21	1.2	0.89	1.56	1.2	0.78	1.84	1.0	0.58	1.57
	Salta	1.3	0.30	5.48	1.2	0.78	1.80	0.9	0.49	1.60	1.3	0.70	2.60
	San Luis	1.2	0.66	2.05	1.2	0.86	1.65	1.3	0.82	2.02	1.1	0.69	1.84
	Santa Fe	1.2	0.74	2.03	1.4	1.26	1.55	1.3	1.08	1.51	1.4	1.20	1.65
	Tucumán	1.1	0.37	3.39	1.6	1.21	2.02	1.2	0.79	1.76	1.6	1.00	2.50
February	Chaco	1.3	0.72	2.18	1.4	1.20	1.68	1.2	0.87	1.52	1.5	1.08	2.07
	Corrientes	1.2	0.70	1.93	1.3	1.08	1.54	1.1	0.84	1.46	1.2	0.92	1.69
	Formosa	1.0	0.57	1.80	1.1	0.84	1.49	1.6	1.07	2.39	1.1	0.64	1.83
	Misiones	1.4	1.11	1.67	1.2	0.97	1.41	1.2	0.92	1.63	1.3	0.93	1.85

*Relative Risk; ‡Confidence Interval 95 %.

Source: Authors, with data provided by the Ministry of Health.

two out of the four provinces involved in the HW in February. In December, the greatest increases in the risk of dying of men were recorded in Santiago del Estero (RR=1.64), Mendoza (RR=1.36) and CABA (RR=1.34). In the HW of January, the risk of dying for males presented greater increases in La Rioja (RR=2.23), Tucumán (RR=1.57) and Santa Fe (RR=1.40). During the HW that took place in February the highest mortality rates for males and the RR significantly increased were found in the provinces of Chaco (RR=1.42) and Corrientes (RR=1.29).

Mortality by age groups

The groups 0 to 19 and 20 to 39 years old did not show increased risk of dying during HWs in none of the provinces.

Only one event showed a significant increase in the risk of dying in the group of 40 to 59 years old: it was in the province of Santiago del Estero during the December 2013 HW (RR=2.44), where 8 cases in the reference period turned into 21 cases during the HW.

In the age group of 60 to 79 years old the risk of dying was increased in at least one province in each of the three HWs during the summer 2013-14 (Table 3). Particularly, an increase in the risk of dying was found in CABA (RR=1.29) and Santa Fe (RR=1.23) during the HW of December 2013, in Mendoza (RR=1.33) and Santa Fe (RR=1.28) during the HW of January 2014 and in Formosa (RR=1.60) during the HW of February 2014. Spatial distribution of the results with significant increase in RR is presented in Figure 3.

The age group over 79 years old had a significant increase in the risk of dying during the December HW in several provinces, with the highest RR value registered in Entre Ríos (RR=2.01), CABA (RR=1.67) and Santa Fe (RR=1.47), while in January 2014 HW significantly increased risk of dying for this age group was found in Tucumán (RR=1.58), Santa Fe (RR=1.41) and Córdoba (RR=1.28); and in February HW in Chaco (RR=1.50).

Mortality and causes of death

Globally speaking during the 266 days (adding up all days in all provinces) under HW in the summer 2013-2014 died 8.759 persons, expressing a risk increase of 1.23 (95%CI 1.20-1.28) over the value in absence of HW. Among them, registered causes of death that have epidemiological evidence of being related to high temperature accounted for 3.736 cases, being the more frequent heart diseases (I30-52 in ICD-10), ischemic heart disease (I20-25), cerebrovascular diseases (I60-69) and pneumonia (J12-18), which together accounted for 77,3% of the total.

Provincial mortality rates and RR were calculated to analyze the mortality linked to causes of death that have epidemiological evidence of being related to high temperature. Thus, statistically significant increases for those causes were found in 10 of the 37 provincial events (5 in December's HW, 4 in January's and 1 in February's), in 6 out of the 18 provinces studied, accounting globally for 1.209 deaths, as presented in Table 4.

The most frequent causes of death with significantly increased RR were pneumonia and ischemic heart disease. Taking into consideration only those cases, pneumonia was responsible for 393 deaths in seven HW events (CABA, Entre Rios, Mendoza and Santa Fe in December, and CABA, Córdoba and Santa Fe in January), being the highest RR (3.18) the one in Mendoza in December; while ischemic heart disease, accounted for 394 cases in five provincial events with significantly increased RR (CABA and Córdoba in December, Córdoba and Mendoza in January and Misiones in February, this one with the highest RR=1.85).

On the other side, during the December 2013 HW, the 49% (481 cases) of all deaths that occurred in CABA were due to causes with heat linked epidemiological evidence, being lower respiratory disease the cause of death with the higher increase of RR (2.32), followed by renal insufficiency (RR=2.28), and pneumonia (RR=2.20). Similar picture was found in Santa Fe, where the higher increases were for lower respiratory disease (RR=2.02 in December and 2.18 in January), pneumonia (RR=2.03 in December and 1.71 in January) and diabetes mellitus (RR=1.99 in January). In Córdoba significative increases included ischemic heart disease (RR=1.83 in December and 1.84 in January), cerebrovascular diseases (RR=1.54 in December) and pneumonia (RR=1.58 in January). Other significative increases were found in Entre Rios (pneumonia in December RR=1.76), Mendoza (pneumonia in December RR=3.18; ischemic heart disease in January RR=1.82) and in Misiones in February (cerebrovascular diseases: RR=2.88; ischemic heart disease RR=1.85).

It is interesting to note that although "exposure to excessive natural heat" (Code X30 in the ICD-10) is a specific cause of death that can be assigned; we found that it is very rare. In our study only 12 deaths among the 8.759 registered during HWs were recorded as that: five cases in Chaco, three in Santa Fe, two in Entre Ríos, one in Corrientes and one in Córdoba; 50% cases in males, 9 out of them in people older than 60 years.

Discussion

In Argentina the frequency of HWs has increased north of parallel 40° South[15]. The summer 2013-2014 was particularly hot with three HWs that covered most of the country, which has been related with a growing number of days with min-

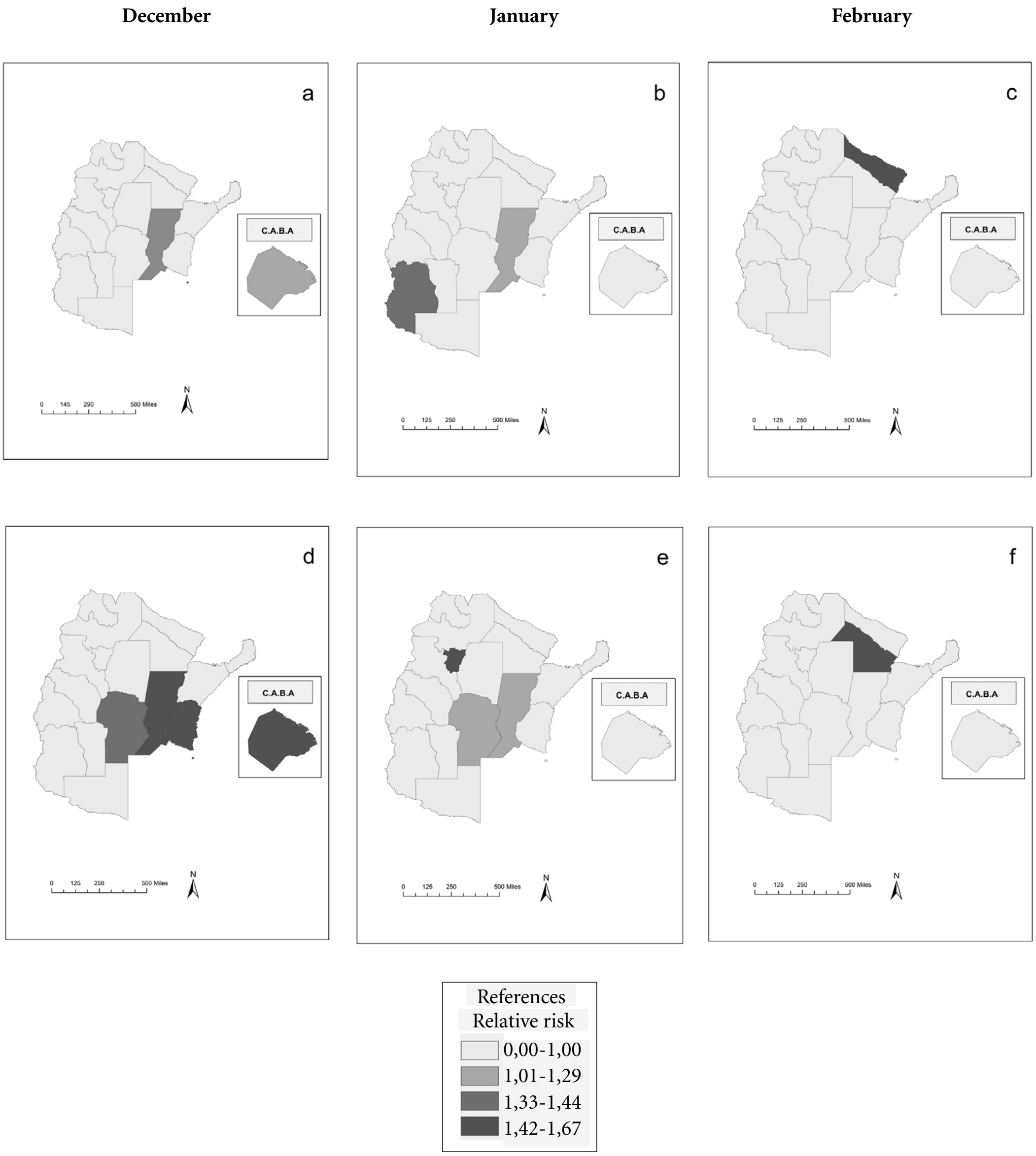

Figure 3. Relative risk maps for age groups 60-79 years old (a, b, c) and over 79 years old (d, e, f) during heat waves of summer 2013-2014 in Argentina.

Source: Authors, with data provided by the Ministry of Health.

imal temperature above historical values rather than with changes in maximal temperatures[29], although regional differences make it difficult to establish a homogeneous pattern.

It is also worth recalling that it has been suggested that the HW that occurred in December 2013 in central and northern Argentina was partially related with anthropogenic forcing; observing that the recurrence time of this event would be 75 years without anthropogenic forcing and 15 years considering such forcing[30].

Overall mortality during the HWs of the summer of 2013-2014 showed heterogeneous behaviour in provinces, yet increases in absolute and relative values were observed in relation to the three previous summer's reference period. In absolute terms there were 1.877 excess deaths, as well as significantly increased risk of dying in 11

Table 4. Groups of morbidities with significantly increased risk during Heat Waves in Argentina, summer 2013-2014.

Causes of death		Buenos Aires City		Córdoba		Entre Ríos	Mendoza		Misiones	Santa Fe	
		Dec.‡	**Jan.§**	**Dec.**	**Jan**	**Dec.**	**Dec.**	**Jan.**	**Feb.‖**	**Dec.**	**Jan.**
Cerebral-vascular disease	Cases			59					46		
	Rates			1.69					3.92		
	RR†			1.54					2.88		
	CI95%			1.03-2.33					1.91-4.36		
Diabetes Mellitus	Cases										29
	Rates*										0.91
	RR†										1.99
	CI95%										1.21-3.29
Ischemic heart	Cases	135		70	95			44	50		
	Rates	4.43		2.01	2.69			2.36	4.26		
	RR†	1.62		1.83	1.84			1.82	1.85		
	CI95%	1.33-1.96		1.23-2.73	1.45-2.35			1.25-2.65	1.30-2.63		
Other forms of heart disease	Cases	189									
	Rates	6.21									
	RR†	1.54									
	CI95%	1.31-1.80									
Chronic lower respiratory tract	Cases	21								26	17
	Rates	0.69								0.85	0.53
	RR†	2.32								2.02	2.18
	CI95%	1.22-4.43								1.03-2.63	1.05-4.52
Pneumonia	Cases	101	37		62	36	13			85	59
	Rates	3.32	1.21		1.76	2.78	0.71			2.77	1.85
	RR†	2.20	1.54		1.58	1.76	3.18			2.03	1.71
	CI95%	1.74-2.80	1.03-2.30		1.17-2.14	1.12-2.14	1.13-8.94			1.40-2.95	1.25-2.33
Renal insufficiency/ kidney failure	Cases	35									
	Rates	1.15									
	RR†	2.28									
	CI95%	1.44-3.60									

*Rates per 100.000 inhabitants. †Only data with statistically significant RRs are shown. ‡December, §January, ‖February.

Source: Authors, with data provided by the Ministry of Health.

of the 18 provinces reached by HWs and in 15 out of the 37 provincial events. Interestingly, the four most populated provinces (CABA, Córdoba, Santa Fe and Mendoza) did presented elevated RR during December and January HWs while, on the other hand, five much less populated provinces (Catamarca, Formosa, Jujuy, La Pampa and San Luis) did not increased their RR during any HW; which could be linked to the fact that in small populations, small changes in the number of deaths can cause great variability in rates and RR, leading to a loss of statistical significance. Nevertheless, it is not clear yet why the impact on mortality varies among provinces. For example, provincial events which lasted about the same, with similar severity in terms of temperature intensity, did show excess numbers of mortal cases or not (San Luis vs La Pampa in December; Tu-

Ciência & Saúde Coletiva, 27(5):2071-2086, 2022

cuman vs. Chaco in January). These differences have been observed in similar studies[4,6,7,31] but the values are difficult to compare due to differences in the scales of phenomena (spatial, temporal and magnitude of HWs). In order to understand these differences new studies at local scale are necessary.

Relative risk of dying could not be undoubtefully linked to any single variable (length of the HW, maximal or minimal temperatures reached, total population, crude number or rate of death in control period). However, higher RR showed a tendency to accompany provinces with bigger cities, as shown in Table 2.

Health impact of a HW could be linked to its intensity, either in terms of temperature and/or the duration, even though differences in baseline reference values do make it difficult to compare phenomena taking place in different locations for a number of reasons. Among them we include differences in local mortality rates, the population socioeconomic profiles – since impoverished people have fewer resources to face hot climate –, importance of activities such as construction and agriculture, based on outdoor tasks, as well as informal work – usually developed in precarious conditions – which naturally generate greater exposure to climatic conditions[3,8-10,32-34].

The importance of acclimatization of individuals to the local conditions in which they live[34-36] is supported by the fact that the temperature of triggering mortality attributable to heat varies from place to place, and indicates that each person is accustomed to living in a range of daily temperatures that is below some threshold.

Other studies suggest that HWs that occurred early in the warm season may have greater effects on the health of the population due to lack of acclimatization[10,36,37], since human physical adaptation to high temperatures can take between two and six weeks[38]. This was not the case here; even when 55.7% of excess deaths occurred during the December HW (1.046 deaths, mortality rate: 4.65 per 100.000 population), the February HW affecting the NEA caused a total of 196 excess deaths (mortality rate: 4.98 per 100.000 population) and recorded significant increases in the risk of dying in three out of the four provinces reached for the event (RR=1.24, 95%CI 1.12-1.36) an event that occurred late in the summer (January 31 to February 12) and in provinces where high temperatures are frequent.

When death of males and females were analyzed separately, HW impact was heterogeneous on both temporal and spatial scales. In the December HW four provinces (CABA, Córdoba, Santa Fe and Santiago del Estero) showed increased risk of dying for both groups, as well as in two other provinces for females and in one province for males. During the January HW the behaviour was very dissimilar: RR in women did not increase significantly in any province while RR in males showed significant increases in 5 provinces. February HW led to increased RR for women in one province (Misiones) and for men in other two provinces (Chaco and Corrientes) out of the four compromised. As a whole for our study, RR>1 was found for men in 12 provincial events and for women in 7 events. Changes in the risk of dying of women between December and January could be explained by a harvesting effect, although that effect was not verified in a previous study in CABA[22].

Thus, no clear association between sex and mortality rates or RR of dying could be drawn. In some events significant increases included both sexes or just one of them, provinces did not keep any pattern even from one HW to the following one, as previously described for several Spanish[36] and Latin American[39] cities but differently from other studies performed in Europe[8,10,40] and Brazil[41,42] suggesting that women are more sensitive than males to HW.

The literature agrees that older adults are at higher risk during HWs[4,10,32,43-45]. The present study found the risk of dying significantly increased in four jurisdictions for the 60-79 years old group and in six jurisdictions for those 80 years old and over, taking together all HWs of the summer 2013-2014. Only one province presented a significant increase in the risk of dying in the group of 40-59 years old during the December 2013 HW and none province presented differences for lower ages.

All causes of death that had a significant increase in risk during HWs have epidemiological evidence and biological plausibility[8-10]. Exposure to extreme heat conditions for long periods can exacerbate a wide range of pre-existing conditions by triggering the chain of pathological events that lead directly to death.

The highest RR in causes of death was recorded for pneumonia; which also had the highest frequency (seven jurisdictions with significantly increased risk). The accumulated cases of respiratory diseases (pneumonia and lower respiratory diseases) were responsible for 457 deaths, only in those jurisdictions where the risk was significantly increased. The incidence of HWs on respiratory disease mortality is consistent with other studies[8]. Cardiovascular disease accounted for 48% of the total causes of death at significantly increased risk observed in five jurisdictions. From these analyses, it would seem that public health programs to prevent heat-related mortality would best be directed at the elderly and those persons with cardiovascular and respiratory diseases.

Despite that the literature[3,11] agrees that living in large cities and different socioeconomic conditions can modify risk levels we did not observe a clear pattern, at least in this particular summer. Perhaps, the analysis unit selected (provinces) is not sensitive enough to analyze the influence of living in large cities.

In conclusion, this study analyzed a particularly warm summer in which three HWs of long duration and intensity were recorded. The characterization of mortality during HWs revealed increases in both absolute and relative values in overall mortality and mortality by sex, age groups and major causes of death heterogeneously along the country. This information was useful in reviewing and expanding the Early Warning System for Heat and Health Waves (SAT-OCS, for its Spanish denomination) in Argentina, implemented operationally in the whole country on the summer 2017-2018[46]. This system operates in an automated manner for 57 locations of the country, issues a daily alert valid for 24 hours and is available online from the first day of October each year to 31 March, with the aim of enabling both the population and civil protection agencies to take appropriate prevention, mitigation and response measures at each alert level.

Collaborations

All authors participated in conceptualization, methodology, formal analysis and writing review. Data acquisition, curation and analysis were performed by F Chesini, N Herrera, MM Skansi and CG Morinigo. Original project writing and editing were made by F Chesini and E de Titto. F Chesini, S Fontán, F Savoy and E de Titto were responsible for financing the acquisition and project administration.

References

1. World Health Organization (WHO). 61ª Asamblea Mundial de la Salud. Cambio climático y salud [Internet]. 2008 [cited 2020 mar 19]. Available from: http://apps.who.int/iris/bitstream/10665/26288/1/A61_R19-sp.pdf.
2. Mercado Común del Sur. Resolución MERCOSUR nº 12/2009. *Estrategia Cambio Climático y Salud. Montevideo* [Internet]. 2009 [cited 2020 mar 19]. Available from: http://200.40.51.218/SAM/GestDoc/PubWeb.nsf/Reunion?OpenAgent&id=CD00D62A0920FF-D7032576A50049C42A&lang=ESP.
3. McGregor GR, Bessemoulin P, Ebi K, Menne B. *Heatwaves and Health: Guidance on Warning-System Development*. Geneva: WHO; 2015.
4. Whitman S, Good G, Donoghue ER, Benbow N, Shou W, Mou S. Mortality in Chicago Attributed to the July 1995 Heat Wave. *Am J Public Health* 1997; 87:1515-1518.
5. Robine JM, Cheung SL, Le Roy S, Van Oyen H, Griffiths C, Michel JP, Herrmann FR. Death toll exceeded 70,000 in Europe during the summer of 2003. *C R Biol* 2008; 331:171-178.
6. Oudin Åström D, Forsberg B, Rocklöv J. Heat wave impact on morbidity and mortality in the elderly population: A review of recent studies. *Maturitas* 2011; 69:99-105.
7. Shaposhnikov D, Revich B, Bellander T, Bedada GB, Bottai M, Kharkova T, Kvasha E, Lezina E, Lind T, Semutnikova E, Pershagen G. Mortality Related to Air Pollution with the Moscow Heat Wave and Wildfire of 2010. *Epidemiology* 2014; 25:359-364.
8. D'Ippoliti D, Michelozzi P, Marino C, Donato F, Menne B, Katsouyanni K, Kirchmayer U, Analitis A, Medina-Ramón M, Paldy A, Atkinson R, Kovats S, Bisanti L, Schneider A, Lefranc A, Iñiguez C, Perucci CA. The impact of heat waves on mortality in 9 European cities: results from the EuroHEAT project. *Environ Health* 2010; 9:37.
9. McGeehin MA, Mirabelli M. The Potential Impacts of Climate Variability and Change on Temperature-Related Morbidity and Mortality in the United States. *Environ Health Persp* 2001; 109:185-189.
10. Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q, Olwoch JM, Revich B, Sauerborn R, Aranda C, Berry H, Butler C, Chafe Z, Cushing L, Ebi KL, Kjellstrom T, Kovats S, Lindsay G, Lipp E, McMichael T, Murray V, Sankoh O, O'Neill M, Shonkoff SB, Sutherland J, Yamamoto S. Human Health: Impacts, Adaptation, and Co-Benefits. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL, editores. *Climate Change 2014: Impacts, Adaptation and Vulnerability. Part A: Global and Sectorial Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge UK: Cambridge University Press; 2014. p. 709-754.
11. Montero JC, Mirón IJ, Criado JJ, Linares C, Díaz J. Difficulties of defining the term "heat wave" in public health. *Int J Environ Health Res* 2013; 23:377-379.
12. Perkins SE. A review on the scientific understanding of heatwaves. Their measurement, driving mechanisms, and changes at the global scale. *Atmospheric Res* 2015; 164-165:242-267
13. Servicio Meteorológico Nacional (SMN). *Argentina. Datos - Clima de Argentina-Olas de calor (Heat waves)* [Internet]. [cited 2020 mar 19]. Available from: https://www.smn.gob.ar/estadisticas.
14. Centro de Investigaciones del Mar y la Atmósfera (CIMA). *Modelos Climáticos: Resumen Ejecutivo (Climate Models: Executive Summary). Secretaría de Ambiente y Desarrollo Sustentable* [Internet]. 2015 [cited 2020 mar 20]. Available from: http://3cn.cima.fcen.uba.ar/3cn_informe.php
15. Rusticucci M, Kysely J, Almeira G, Lhotka O. Long-term variability of heat waves in Argentina and recurrence probability of the severe 2008 heat wave in Buenos Aires. *Theor Appl Climatol* 2015; 124:679-689.
16. Cerne SB, Vera CS. Influence of the intraseasonal variability on heat waves in subtropical South America. *Clim Dyn* 2011; 36:2265-2277.
17. Geirinhas JL, Russo A, Libonati R, Sousa PM, Miralles DG, Trigo RM. Recent increasing frequency of compound summer drought and heatwaves in Southeast Brazil. *Environ Res Lett* 2021; 16:034036.
18. Cerne B, Vera C, Álvarez M. Influencia de la variabilidad intraestacional en el desarrollo de la ola de calor de diciembre de 2013 en el este de Sudamérica. In: *Congreso Argentino de Meteorología (CONGREMET) XII*. Mar del Plata; 2015 maio 26-29.
19. Osman M, Álvarez M. Subseasonal prediction of the heat wave of December 2013 in Southern South America by the POAMA and BCC-CPS models. *Climate Dynamics* 2018; 50(1-2):67-81.
20. Abrutzky R, Dawidowski L, Matus P, Romero-Lankao P. Health effects on climate and air pollution in Buenos Aires. A first series analysis. *J Environ Prot* 2012; 3:262-271.
21. Almeira G, Rusticucci M, Suaya M. Relación entre mortalidad y temperaturas extremas en Buenos Aires y Rosario. *Meteorológica* 2016; 41:65-79.
22. Chesini F, Abrutzky R, de Titto EH. Mortalidad por olas de calor en la Ciudad de Buenos Aires, Argentina (2005-2015). *Cad Saude Publica* 2019; 35:e00165218.
23. Instituto Nacional de Estadística y Censos (INDEC). *Argentina. Censo Nacional 2010 de Población, Hogares y Viviendas* [Internet]. [cited 2020 mar 18]. Available from: http://www.indec.gov.ar/index.asp.
24. Dirección Nacional de Estadísticas e Información de la Salud (DEIS). *Indicadores Básicos Argentina 2014* [Internet]. Buenos Aires: Ministerio de Salud de la Nación; 2015 [cited 2020 mar 20]. Available from: http://www.deis.gov.ar/publicaciones/archivos/indicadores_2014.pdf.
25. Culqui DR, Díaz J, Simón F, Linares C. Análisis de los impactos de las olas de calor sobre la mortalidad de la ciudad de Madrid durante el período 1990-2009. *Rev Esp Salud Pública* 2013; 87:277-282.
26. Beaglehole R, Bonita R, Kjellström T. *Epidemiologia Básica*. Washington D.C.: PAHO; 1994.

27. Carracedo-Martínez E, Tobías A, Saez M, Taracido M, Figueras A. Fundamentos y aplicaciones del diseño de casos cruzados. *Gac Sanit* 2009; 23:161-165.
28. Martín JF. Los factores definitorios de los grandes grupos de edad de la población: tipos, subgrupos y umbrales. *Scripta Nova* 2005; IX:190.
29. Centro Regional del Clima para el Sur de América del Sur (CRC-SAS). *Climatología – Tendencias de Índices de Extremos Climáticos* [Internet]. [acessado 2020 mar 20]. Disponível em: https://www.crc-sas.org/es/climatologia_extremos_climaticos.php.
30. Hannart A, Vera C, Otto FE, Cerne B. Causal influence of anthropogenic forcings on the Argentinean heat wave of December 2013. *Special Suppl Bull Am Meteorol Soc* 2015; 96:541-545.
31. World Meteorological Organization. World Health Organization (WHO). *Atlas del Clima y la Salud*. Ginebra: WHO; 2012.
32. McGregor GR, Pelling M, Tanja Wolf T, Gosling S. *United Kingdom Environment Agency Science Report* [Internet]. Bristol; 2007 [cited 2020 mar 20]. Available from: www.environment-agency.gov.uk.
33. Son J-Y, Gouveia N, Bravo MA, Freitas CU, Bell MK. The impact of temperature on mortality in a subtropical city: Effects of cold, heat, and heat waves in São Paulo, Brazil. *Int J Biometeorol* 2016; 60:113-121.
34. Guo Y, Gasparrini A, Armstrong BG, Tawatsupa T, Tobias A, Lavigne E, Coelho MSZS, Pan X, Kim H, Hashizume M, Honda Y, Guo YL, Wu CF, Zanobetti A, Schwartz JD, Bell ML, Scortichini M, Michelozzi P, Punnasiri K, Li S, Tian L, Garcia SDO, Seposo X, Overcenco A, Zeka A, Goodman P, Dang TN, Dung DV, Mayvaneh F, Saldiva PHN, Williams G, Tong S. Heat Wave and Mortality: A Multicountry, Multicommunity Study. *Environ Health Perspect* 2017; 125(8):087006.
35. Curriero FC, Heiner KS, Samet JM, Zeger SL, Patz JA. Temperature mortality in 11 cities of the Eastern of the United States. *Am J Epidemiol* 2002; 155(1):80-87.
36. Díaz J, Jordán A, García R, López C, Alberdi JC, Hernández E, Otero A. Heat waves in Madrid 1986-1997: effects on the health of the elderly. *Int Arch Occup Environ Health* 2002; 75(3):163-170.
37. Anderson GB, Bell ML. Heat Waves in the United States: Mortality Risk during Heat Waves and Effect Modification by Heat Wave Characteristics in 43 U.S. Communities. *Environ Health Perspect* 2011; 119(2):210-218.
38. Guyton AC, Hall JE. *Textbook of Medical Physiology*. Philadelphia: Elsevier Saunders; 2006.
39. Bell ML, O'Neill MS, Ranjit N, Borja-Aburto VH, Cifuentes LA, Gouveia NC. Vulnerability to heat-related mortality in Latin America: a case-crossover study in São Paulo, Brazil, Santiago, Chile and Mexico City, Mexico. *Int J Epidemiol 2008;* 37(4):796-804.
40. Ishigami A, Hajat S, Kovats RS, Bisanti L, Rognoni M, Russo A, Paldy A. An ecological time-series study of heat-related mortality in three European cities. *Environ Health* 2008; 7:5.
41. Geirinhas JL, Trigo RM, Libonati R, Castro LCO, Sousa PM, Coelho CAS, Peres LF, Magalhães FMA. Characterizing the atmospheric conditions during the 2010 heatwave in Rio de Janeiro marked by excessive mortality rates. *Sci Total Environ* 2019; 650:796-808.
42. Geirinhas JL, Russo A, Libonati R, Trigo RM, Castro LCO, Peres LF, Magalhães MAFM, Nunes B. Heat-related mortality at the beginning of the twenty-first century in Rio de Janeiro, Brazil. *Int J Biometeor* 2020; 64(8):1319-1332.
43. Conti S, Meli P, Minelli G, Solimini R, Toccaceli V, Vichi M, Beltrano C, Perini L. Epidemiologic study of mortality during the Summer 2003 heat wave in Italy. *Environ Res* 2005; 98:390-399.
44. Martínez Navarro F, Simón-Soria F, López-Abente G. Valoración del impacto de la ola de calor del verano de 2003 sobre la mortalidad. *Gac Sanit* 2004; 18(Supl. 1):250-258.
45. Linares C, Díaz J. Temperaturas extremadamente elevadas y su impacto sobre la mortalidad diaria según diferentes grupos de edad. *Gac Sanit* 2008; 22:115-119.
46. Herrera N, Skansi MM, Berón M, Campetella C, Cejas A, Chasco J, Chesini F, de Titto E, Gatto M, Saucedo M, Suaya M. *Sistema de Alerta Temprana por Olas de Calor y Salud (SAT-OCS). Technical note SMN 2018-50* [Internet]. 2018 [cited 2020 mar 20]. Available from: http://repositorio.smn.gob.ar/handle/20.500.12160/772.

Article submitted 30/11/2020
Approved 29/07/2021
Final version submitted 01/08/2021

Chief editors: Romeu Gomes, Antônio Augusto Moura da Silva