

# Exceptionally high mortality rate of the 1918 influenza pandemic in the Brazilian naval fleet

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**Background** The naval experience with the 1918 pandemic during World War I remains underexplored despite its key role on the pandemic's global diffusion and the epidemiological interest of isolated and relatively homogeneous populations. The pandemic outbreak in the Brazilian naval fleet is of particular interest both because of its severity and the fact that it was the only Latin American military force deployed to war.

**Objectives** To study the mortality patterns of the pandemic in the Brazilian fleet sent to patrol the West African coast in 1918.

**Method** We investigated mortality across vessels, ranks, and occupations based on official population and mortality records from the Brazilian Navy Archives.

**Results** The outbreak that swept this fleet included the highest influenza mortality rate on any naval ship reported to date. Nearly

10% of the crews died, with death rates reaching 13–14% on two destroyers. While overall mortality was lower for officers, stokers and engineer officers were significantly more likely to die from the pandemic, possibly due to the pulmonary damage from constant exposure to the smoke and coal dust from the boilers.

**Conclusions** The fatality patterns observed provide valuable data on the conditions that can exacerbate the impact of a pandemic. While the putative lack of exposure to a first pandemic wave may have played a role in the excessive mortality observed in this fleet, our results indicate that strenuous labor conditions, dehydration, and exposure to coal dust were major risk factors. The unequal death rates among vessels remain an open question.

**Keywords** 1918, Brazil, influenza, navy, pandemic.

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## Introduction

World War I had the second highest mortality burden of any war in absolute numbers (after World War II), causing approximately 9·2 million combat deaths worldwide. Yet, although overshadowed by the events of war, the influenza pandemic that swept the globe in 1918–1919 killed more victims in the last months of the war than the total number of battlefield deaths during the entire war period. Mortality estimates based on vital registration records range from approximately 20 to 50 million deaths worldwide<sup>1–3</sup> at a time when the world population was estimated at 1·8 billion people (a quarter of today's population), making the 1918 pandemic one of the most devastating public health crises of recent history.

Influenza is a highly contagious viral disease typically transmitted through airborne aerosols produced by infected persons during coughing and sneezing, or by direct contact

with nasal secretions or surfaces contaminated with the virus.<sup>4</sup> Because influenza can be easily transmitted from person to person in confined and crowded spaces, the large masses of people on the trenches, military camps, and troopships of World War I created the ideal setting for the rapid spread of the disease. The 1918 pandemic was also especially deadly among the armed forces as, in contrast to seasonal influenza epidemics that affected predominantly children and the elderly, most of this pandemic's victims were young healthy adults.<sup>5,6</sup>

Not only did the 1918 outbreak render millions of military personnel ineffective, but the massive movements of people during the war also played a critical role on the rapid global transmission of the virus. Troopships and naval convoys contributed to the rapid diffusion of the pandemic across continents. Still, with the exception of some careful descriptions of the 1918 pandemic outbreak in some naval ships from the United States, Australia, and

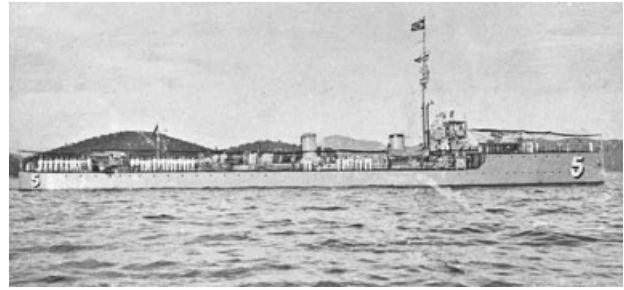
New Zealand,<sup>7–9</sup> there are few recent reports on the naval experience with pandemic influenza. The analysis of the mortality patterns in isolated and relatively homogeneous populations (in terms of age, occupation, health status, and living conditions) such as those from naval fleets can yet provide important clues about the dynamics and impact of this and future pandemics. The purpose of this study is to investigate the 1918 influenza pandemic in the Brazilian Naval Division of War Operations (hereafter DNOG, its Brazilian acronym), a fleet consisting of eight vessels (two cruisers, four destroyers, one transport ship, and one ocean tugboat) sent to patrol the northwest coast of Africa in 1918. The DNOG represented the naval force of the only Latin American nation that took an active part in the conflict and was the largest Brazilian military force deployed to the northern hemisphere.<sup>10–12</sup>

On May 1918, the Brazilian fleet departed Rio de Janeiro (Brazil) under the command of Admiral Pedro de Frontin. Although attacked by a German submarine on August 25, the voyage was in general uneventful: The naval fleet reached Freetown (Sierra Leone) on 9 August, where it stayed until August 23, and docked in Dakar (Senegal) on August 26, where it would stay a few days for repairs. But soon after the convoy's arrival in Dakar, pandemic influenza swept through the fleet,<sup>13</sup> infecting as much as 90% of the crew of some vessels.<sup>12</sup> Many of those infected perished and were buried in Dakar. Here, we describe the mortality patterns in this naval fleet, further investigating the temporal dynamics of mortality and potential differences among ships, main labor conditions, and military ranks.

## Methods

### Study population

Data on all individuals onboard every ship on the Brazilian fleet (DNOG) were directly transcribed from the official book of records available in the Archives of the Brazilian Navy in Rio de Janeiro<sup>13</sup> and from the list provided by Maia.<sup>11</sup> The study population included all individuals listed, as of June 17 (1918), onboard the cruisers “Rio Grande do Sul” and “Bahia,” and the four torpedo-boat destroyers “Parahyba” (Figure 1), “Rio Grande do Norte,” “Piahy,” and “Santa Catarina.” Entries containing the name, military occupation, and vessel of each individual were tabulated and inspected for consistency. Since June 17, the transport ship Belmonte and the ocean tugboat Laurindo Pita had still not departed from Rio de Janeiro information on their population was organized only later by Maia.<sup>11</sup> This author mentions the possibility of duplicate names in the latter list (as crew originally assigned to other ships may have worked on Belmonte and L. Pita at some point until the return of the fleet to Brazil), so all records were cross-checked. True duplicates were those for which there was a



**Figure 1.** Destroyer Parahyba (CT-5) (DNOG Photography Collection, Archives of the Brazilian Navy). Of a population of 102 men onboard this ship, 14 men (13.7%) died from pandemic influenza during the expedition to Dakar in 1918.

match between the name, surnames, and military occupation of the individual. Accordingly, there were 98 and six individuals listed on Belmonte and L. Pita, respectively, who were already present in the lists of other ships. The presence of duplicates in Belmonte was further confirmed by the observation that this ship had 100 sailors more than the two other cruisers, even though all cruisers had the same capacity. Therefore, all duplicates were excluded from the crew lists of Belmonte and L. Pita.

### Mortality

Historical information on mortality because of the influenza pandemic (individual records of death, death dates, and locations) was ascertained from the official mortality records issued by the Brazilian Naval Division<sup>11,14,15</sup> and the Senegalese authorities,<sup>16</sup> as well as from the official daily reports issued by the officers onboard the convoy. All mortality records were cross-checked among sources to determine their consistency. In those few cases where the date of death was not the same in different reports, we assumed that the date most likely to be correct was that obtained directly from the official daily reports. The report issued by the Senegalese authorities<sup>16</sup> also provided the location of death (whether onboard or in Dakar's hospital) for all individuals who died during September and October 1918. Although the cause of death was not cited in the mortality records examined, the official daily reports issued by the convoy's officers included lists of those who died from the pandemic. Therefore, we also examined these reports to determine which deaths could be unequivocally attributed to the pandemic.

### Military occupation

Previous studies have indicated the existence of potential differences between officers and non-officers in terms of morbidity and mortality resulting from a number of illnesses and infectious diseases – including influenza.<sup>7</sup> Therefore, the data analysis was conducted separately for officers

and ordinary crew members. Previous research has also noticed a higher prevalence and severity of some diseases among stokers, given the highly intense physical nature of their work, usually performed under high temperatures at confined environments.<sup>17</sup> We therefore further divided crew members into two groups – stokers (those in charge of tending the boilers and shoveling coal into the firebox) and sailors (all enlisted personnel who were neither officers nor stokers, regardless of their occupations or ranks) – to investigate potential differences between these groups.

## Results

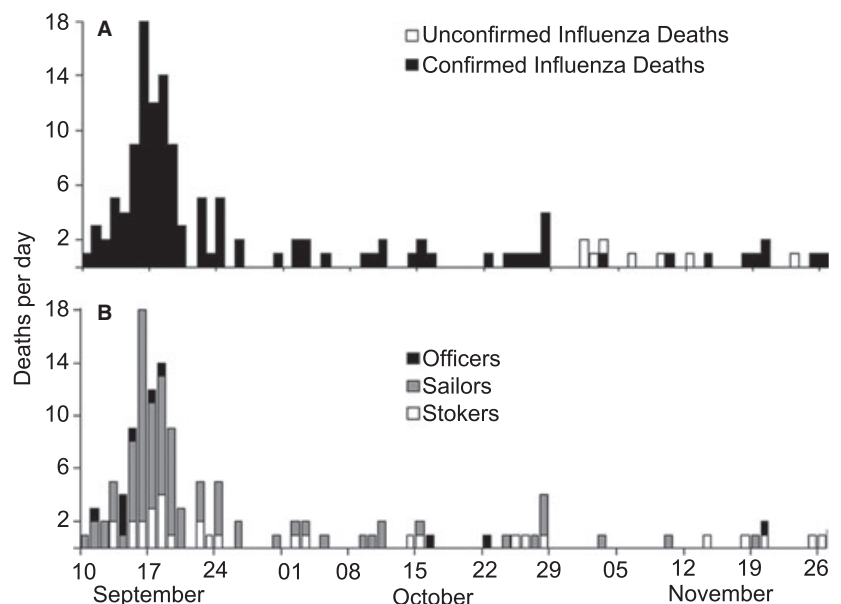
There were 1527 men (and no woman) onboard the Brazilian convoy that went to Dakar (339, 351, and 356 in each of the three cruisers; 102, 107, 109, and 109 in the four destroyers, 36 in the tugboat, and 18 without a specific ship assigned). Although a precise description of each individual's age and time in the military is not yet available, typical ages ranged from 22 to 35 years in the case of officers and from approximately 16 to 40 years for the remaining crew.<sup>13</sup> Most men were either descendants of Portuguese immigrants or Afro-Brazilians, as revealed by the analysis of surnames in the crews lists: The surname of 97.2% of the population onboard had a Portuguese origin (free slaves were often named after their former owners, so their descendants also had Portuguese surnames), followed by Italian (0.7%), Spanish (0.5%), or surnames with other ethnic origins (1.6%).

The first death from influenza occurred on September 10, suggesting that the first infections were approximately

between late August and early September. In the days that followed, the number of deaths increased very rapidly, with mortality reaching a peak (18 deaths on a same day) less than a week after the first death, on September 16 (Figure 2A). Similarly, mortality steeply decreased from September 18 until September 26, being maintained at 1–2 deaths per day until the end of November. Overall, a total of 157 men (10.2%) on the Brazilian fleet died until the mission returned to Brazil, of which 125 deaths (8.2%) had pandemic influenza described as the cause of death in the official daily reports issued by the ships' officers (Table 1 and black bars in Figure 2A). The last confirmed influenza deaths were in November 1918, with previous reports suggesting that the remaining deaths (white bars in Figure 2A) were from other diseases, such as beriberi (a disease caused by vitamin B1 deficiency<sup>17</sup>) and malaria,<sup>12</sup> as well as from injuries onboard.<sup>15</sup> The temporal distribution of the number of influenza deaths was similar to the general pattern described earlier when each vessel was analyzed separately (Figure 3).

Although overall mortality rates (from influenza and other causes) were highest in the destroyer Santa Catarina, with nearly 18% of the total population of this vessel dying, the ship worst affected by the pandemic was the destroyer Parahyba (Figure 1), where nearly 14% of the men onboard died from pandemic flu (Figure 4). Pandemic mortality rates were also extremely high in the other vessels, ranging from 13% (destroyer Santa Catarina) to approximately 4% in the least affected ship (destroyer Rio Grande do Norte; Figure 4). Figure 4 shows that all vessels were nearly at or over their full capacity (as indicated by a

**Figure 2.** Temporal distribution of the (A) total number of deaths in the Brazilian naval fleet from September 10 to November 26, 1918 (the date of the last confirmed influenza death), where black and white bars represent deaths from influenza and other causes, respectively, and (B) of the number of pandemic influenza deaths among officers, sailors, and stokers.

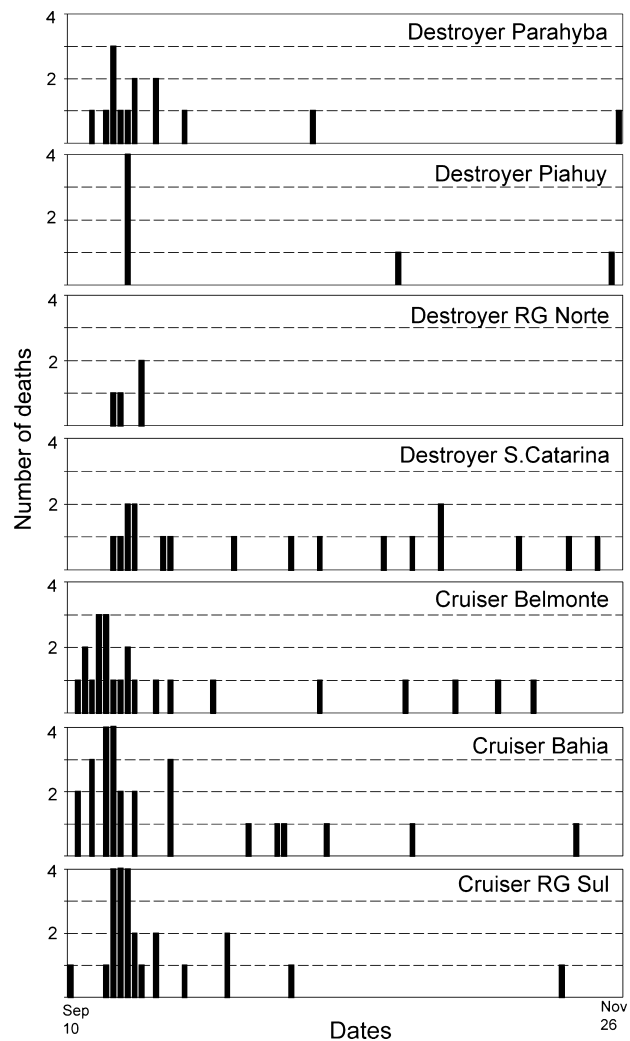


**Table 1.** Number of deaths from pandemic influenza and from all causes (deaths from pandemic influenza and those where cause of death was not mentioned) among officers, sailors, and stokers onboard the Brazilian naval fleet. Mortality rates are shown in brackets

Rank	Deaths from pandemic influenza	Total deaths (pandemic + cause not cited)	Total population
Officer	10 (6.8%)	10 (6.8%)	146
Sailor	85 (7.7%)	106 (9.6%)	1107
Stoker	30 (10.8%)	41 (14.7%)	278
Total	125 (8.2%)	157 (10.2%)	1531

crowding index under the name of each ship, calculated by dividing the total number of people onboard by the vessel's full capacity). However, there was no obvious association between the observed differences in mortality among the vessels and their population, crowding index, or the relative proportion of officers, sailors, and stokers onboard (bivariate correlations:  $P > 0.05$  in all cases). Similarly, there were no obvious differences in the routes performed, or in the vessels' technical classifications, which could explain the observed differences in mortality (those vessels with the highest and lowest mortalities were both destroyers with the same technical specifications and capacity, and both followed nearly the same route to Dakar).

Differences in the proportion of deaths were, however, observed among officers, stokers, and sailors (Figure 5). Stokers were the most affected group, with approximately 10.8% of this group dying from the pandemic influenza and nearly 15% of all stokers dying (all deaths) during the naval expedition. Figure 2B shows that deaths in the former group (white bars) were observed a few days after the first death in the convoy and were more evenly distributed in the course of the pandemic period, with a less steep peak of mortality. Officers, in turn, had the lowest mortality rate (6.8%). In total, 10 officers died (all from pandemic influenza): two physicians (of six physicians in the fleet; none of the eight enlisted nurses died), two lieutenants, and six engineers (or 10.9% of the 55 engineers onboard). Although the proportion of officers sent back to Brazil (15 in total, corresponding to approximately 10% of the officers in the squadron<sup>11</sup>) during September and October as a consequence of the pandemic was similar to that of non-officers (125, or 9% of all non-officers), the analysis of the official Senegalese records shows that while 80% of the officers died in the hospital in Dakar, sailors and stokers mostly died onboard the ships (the percentages of deaths in hospital among sailors and stokers were, respectively, 21% and 31%, significantly lower than those of officers; Fisher's exact test:  $P = 0.017$ ). This indicates that sick



**Figure 3.** Temporal distribution of the number of deaths from pandemic influenza in each vessel of the Brazilian naval fleet.

officers received more nursing care ashore than did sailors remaining on the ships. We additionally determined the potential influence of ethnic origin, as determined by surnames, on mortality. Although the mortality rate among those with a Portuguese surname was higher (11.5%) than those with surnames of other ethnic origins (4.9%), possibly reflecting the fact that there were more non-Portuguese surnames among officers (8.2%) than among other crew members (2.3%), the difference was not significant (Fisher's exact test:  $P = 0.31$ ).

As the mortality rate of engineer officers (nearly 11%, or six of 55) was similar to that of stokers (the most affected group), we examined whether exposure to the potentially damaging conditions of the engine rooms (shared by stokers and engineers and characterized by high temperatures and levels of coal dust) was a major risk factor by conducting a binary logistic regression having death as the binary

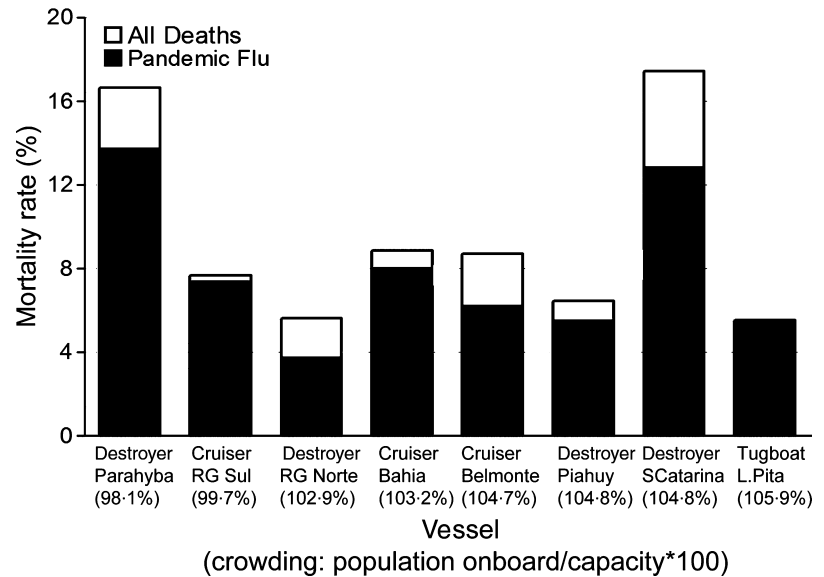


Figure 4. Mortality rate (%) from influenza and from other causes in each vessel of the Brazilian Naval fleet. The numbers between brackets are a measure of crowding within each ship, calculated as the total number of people onboard the ship divided by its full capacity (in number of people).

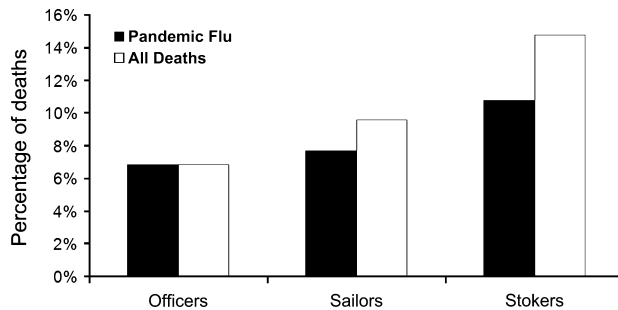


Figure 5. Mortality rates for influenza and other causes by the different occupational groups.

outcome. To separate the effect of military rank from the effect of working environment, we used two categorical variables as predictors: rank (two levels: officers and ordinary crew) and working environment (two levels: engine rooms and other). In the model including all deaths (confirmed and suspected), ordinary crew members were nearly twice more likely to die than officers ( $P = 0.05$ , odds ratio = 1.98, 95% CI: 0.98–4.00). Working in the engine rooms had a similar effect on overall mortality ( $P = 0.003$ , odds ratio = 1.76, 95% CI: 1.22–2.55). When only confirmed influenza deaths were modeled, the only predictor significantly associated with mortality was working environment: Those working in the engine rooms were 1.5 times more likely to die from pandemic influenza ( $P = 0.03$ , odds ratio = 1.57, 95% CI: 1.04–2.38), independently of their rank.

## Discussion

The epidemic that spread in the Brazilian naval fleet at the end of World War I represented the first contact of any

Brazilian population with the 1918 influenza pandemic and included the highest pandemic mortality rates in any navy reported to date. Most deaths occurred in mid-September, overlapping the second wave of the pandemic in West Africa.<sup>18</sup> Although it is not possible to rule out the possibility that the outbreak in the Brazilian fleet had its origin in Dakar, it is more likely that infection occurred through contact with the British ships, infected in Freetown and also docked in Dakar in late August.<sup>12</sup> The latter possibility is also reinforced by an official Senegalese report which refers to the 1918 outbreak in Dakar as the “Brazilian influenza,”<sup>19</sup> indicating that the outbreak in the Brazilian fleet may have preceded the notification of cases in the local population. Overall, over 10% of the crew died until the return of the squadron to Brazil, of which at least 8.3% deaths were officially reported as because of influenza. An additional 10% of the crew was sent back to Brazil after falling ill with the flu. The analysis of the temporal distribution of deaths shows that the number of deaths increased steeply in a short period of time (a few days), peaking in <1 week after the first death and then falling rapidly, consistent with the observation that the spread and decline of highly pathogenic infectious diseases is faster in closed communities.<sup>9</sup>

The analysis of mortality per ship showed that there were no specific trends in terms of mortality based on absolute population numbers or crowding in the ships. However, in line with previous studies,<sup>7,20</sup> consistent differences were observed in the proportion of deaths among military ranks, with officers experiencing lower overall mortality. It is possible that the likely better health and nutritional status experienced by officers (who were in general from much higher socioeconomic classes than



ordinary crew members and directly recruited from the Naval war college), as well as better nursing care and living conditions in the ships, may have translated into a lower risk of mortality.<sup>21</sup> Previous research<sup>7</sup> also suggests that those with a shorter time in the military, or younger age, were more immunologically susceptible than were older officers. The observation that Australian soldiers who had experienced respiratory illnesses earlier in 1918 had a lower risk of mortality during the more severe influenza outbreak in the last months of 1918<sup>7</sup> also indicates the importance of previous respiratory infections. This possibility is reinforced by the observation<sup>20,22</sup> that in Australia, Britain, and the United States, pneumonia–influenza-related mortality during the second wave of the 1918 pandemic was lower among nurses and physicians than for any other occupational group, despite their extensive exposure to the pandemic strain. It is difficult to determine, however, whether these observations find additional support in the data from the Brazilian fleet, as our documental sources did not include individual ages and the medical or military history of most of the crew.

The observed differences in the proportion of deaths between officers and ordinary crew members were, however, only significant for overall mortality rates, but not for confirmed pandemic death rates. Our results suggest that, instead, a major factor determining the likelihood of dying from the pandemic was exposure to the extreme conditions of the engine rooms. Indeed, the higher proportion of deaths among stokers and engineer officers indicates that constant exposure to the smoke and coal dust from the boilers in the engine rooms, and likely pulmonary damage and oxidative stress of the respiratory epithelial cells, was a major factor exacerbating the effects of the pandemic infection. A similar observation was also made in a report from 1920, which mentioned that mortality from pandemic influenza among coal miners from Ohio was much higher than for similar occupation groups.<sup>23</sup> Likewise, exposure to diesel exhaust has been shown to increase the ability of the influenza virus to attach to and enter respiratory epithelial cells.<sup>24</sup> It is worth noticing that in the case of the Brazilian fleet, the equally high death rates experienced by engineers and stokers indicate that the increased susceptibility to severe infection and death caused by the conditions in the engine rooms was independent of potential differences in age, ethnicity, medical history, and socioeconomic background between these two groups.

The explosive nature of the outbreak observed in the Brazilian fleet was only matched by that observed among a few other military ships from Australia and New Zealand.<sup>8</sup> Although there are no precise records of the number of people who were infected with influenza onboard the Brazilian naval fleet, a report from 1921 by an official who

participated in the 1918 naval mission mentions that influenza similarly developed in nearly 90% of the population of the ships.<sup>12</sup> According to the report, the number of infected personnel onboard the cruiser Bahia tripled in 1 day from 70 to 200 infected men from September 6 to September 7. The speed with which the infection spread onboard one of the other cruisers (Rio Grande do Sul) was such that in <24 hours, the number of symptomatic infected personnel increased from 30 (September 7) to 160 (September 8). According to the same author, there were over 300 people (approximately 90% of the crew) simultaneously ill with influenza in the Rio Grande do Sul during the peak of the pandemic, with a similar morbidity rate observed in the other vessels.

In terms of mortality, the death rates observed in the destroyers Parahyba and Santa Catarina (nearly 14% and 13%, respectively) are, to our knowledge, the highest influenza mortality rates reported on any ship during the war, followed by a few troopships from New Zealand and Australia.<sup>8</sup> Although there are no precise morbidity records to enable the calculation of case fatality ratios or the reproduction number of the pandemic, the few descriptions from the Brazilian survivors of the outbreak indicate an extremely rapid transmission. The high morbidity and mortality reported may have resulted from a combination of factors. First, the relative isolation of the Brazilian crew in the southern hemisphere may have played a role in the mortality patterns observed. The pandemic that struck the Brazilian navy in 1918 includes the highest mortality rates observed among naval warships. Other warships with extreme mortality rates during the 1918 influenza pandemic include the USS Pittsburgh (6.9%) in Rio de Janeiro, HMS Africa (6.6%) in Freetown, and Sierra Leone and IJN Yahagi (11.6%) in Manila, Philippines.<sup>25</sup> All were on patrol duty in the southern hemisphere as was the Brazilian squadron prior to its deployment to West Africa. The majority of US and British Royal Navy ships in the northern hemisphere had no influenza deaths during the influenza pandemic.<sup>25</sup> It is possible that a lack of exposure to the first wave of the pandemic, which caused high morbidity with very little mortality from March to May 1918 in the northern hemisphere,<sup>25–28</sup> may have translated into lower levels of immunity against the pandemic strain among those squadrons isolated in the South. Currently, there is no data or report that indicates the presence of a first pandemic wave previous to September 1918 in Brazil, although it is not possible to rule out the possibility that it may have been mistaken by seasonal influenza. Additionally, the report of lower case fatality ratios (up to 2.5%) among the military population working onboard the Brazilian naval fleet docked in the Brazilian coast suggests that a potential lack of immunity was likely not the sole factor contributing to the exceptionally high mortality in the

DNOG sent to Dakar.<sup>30</sup> Another risk factor relates to the sanitary, working, and living conditions onboard the fleet. In the crowded ships, where a large number of people were in close contact with shared sleeping and feeding facilities, the implementation of isolation and control policies was impossible.<sup>29</sup> This is especially true in the case of the Brazilian squadron, which had most vessels over their full capacity.<sup>12</sup> Importantly, in addition to the lack of healthy personnel to operate the most basic maintenance services in the peak of the pandemic (including sanitation, cooking, and maintenance of electrical power), there was a reported shortage of drinkable water in the Brazilian fleet,<sup>11</sup> which by worsening the dehydration caused by influenza may have increased the likelihood of death. This shortage of drinkable water and the long hours of work under the heat and sun of the West African coast indicate that dehydration may have also played a key role in the high death rates observed in the Brazilian fleet. In summary, the excessive mortality observed in the Brazilian fleet represents an interesting case from which to gather valuable knowledge on the conditions that can exacerbate the impact of an influenza pandemic. Still, the observed differences in the mortality rates among the Brazilian warships remain an open question.

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