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How to control cruise ship disease risk? Inspiration from the research literature

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\begin{abstract}
The COVID-19 pandemic once brought the global cruise industry to a standstill. This has led to the realization that the development of viable disease risk management policies and measures will guarantee the sustainability of cruise tourism. The purpose of this study is to identify and develop a framework for risk management of cruise ship disease based on the research literature of cruise diseases in the Web of Science from 1996 to 2019. The study analyzed the characteristics of the literature researchers, the relationships between their research institutions, the main cruise ship disease cases and measures. Based on the discussion of COVID-19 on cruise ships, risk management factors of cruise ship diseases were proposed, which include the port country’s epidemic prevention capacity, the mode of disease transmission, the relevant regulations on international public health disposal, the design and construction of cruise ships, the medical and health conditions on cruise ships, and the characteristics of cruise tourism activities. A timeline and system framework for cruise ship disease risk management is proposed. A special "maritime mobile community prevention and control system" should be established, and a cooperation mechanism consisting of the government, non-governmental organizations, trade groups and industry experts should be established. The port should be capable of border isolation, detection and establishment of temporary shelter hospitals. At the same time, big data technologies such as disease tracking, investigation and health data are also important components of the risk management system.
\end{abstract}

1. Introduction

As the fastest growing sector of the global tourism industry, cruise tourism has drawn extensive attention. Over the past 40 years, although the global economy has experienced many economic recessions and fluctuations triggered by various factors, the number of cruise passengers has maintained an average growth of about 7%. The cruise industry plays an important role in the global economy, creating 1177,000 jobs, sending out $50.024 billion in payroll and generating $150 billion in global revenue in 2018 [1]. Cruise ships, known as "maritime mobile community," are characterized by large passenger capacity, high personnel density, long gathering time, narrow internal environment, relatively concentrated diet and many sailing places, etc. It is more likely to lead to collective outbreaks of infectious diseases than land communities [2].

As of 9:30 a.m. CET on 12 December 2020, 69,521,294 confirmed cases of COVID-19, including 1582,674 deaths, have been reported to WHO worldwide [3]. Although this is the third epidemic caused by coronavirus in the 21st century, the number of people infected now exceeds that of the first two combined [4,5]. The negative impacts of COVID-19 are not limited to human casualties but also include short- and long-term social, economic and political impacts. The International Monetary Fund (IMF) predicts that the global economy could contract by 3% in 2020, while the loss of GDP due to the epidemic situation could reach around $9 trillion [6]. The UNWTO estimates that the wide-spread of the novel coronavirus has resulted in the loss of about 1.1 billion international tourists, a drop in export earnings of between $91 billion and $1.1 trillion and the loss of between 100 million and 120 million jobs [7]. This is more serious than the global impact of the 2003 SARS epidemic and has severely affected the economic growth and prosperity of some countries [8,9].

Accordingly, the threat to global public health posed by international tourism during the COVID-19 pandemic should also be fully recognized [10]. Farzanegan et al. (2020) found that there was a positive correlation between international tourism and the cumulative level of COVID-19 confirmed cases and deaths by April 30, 2020 [11]. Cruise
tourism, which is highly dependent on global mobility, has exacerbated this situation. Major cruise companies such as Carnival, Royal Caribbean and Norwegian have witnessed a rapid increase in COVID-19 cases among passengers and crew members [11]. The market value of a number of cruise companies has shrunk dramatically. Among them, the stocks of Royal Caribbean Cruises, Carnival and Norway’s three major cruise companies have fallen by an average of 84.2% in 62 days [12], leaving the global cruise industry to a standstill.

Since the worldwide suspension of cruises, the international cruise industry has carefully reflected on the lessons of the infection incidents of cruise tourists in Yokohama, Japan in the early stages of the epidemic [13], and has actively studied safety and health measures and risk prevention mechanisms for the resumption of cruises. The Health Program of European Union has developed guidelines for the resumption of cruise ships called Healthy Gateways [14]. The Health Sail Panel has formulated 74 anti-epidemic recommendations for the resumption of cruise ships in North America, called "Recommendations from the Healthy Sail Panel" [15]. Some countries and regions around the world have resumed cruise ships [16]. However, among the cruise ships that have resumed sailing around the world, some cruise ships have been suspended due to the epidemic [16].

In the "Research Report on Restart of Chinese Cruise Industry", it is argued that the "cruise safety bubble" is a strategy for resuming sailings in other countries and regions of the world where the outbreak has not been controlled and is still in a high and medium risk environment [17]. "The strategy is to create a small, secure and enclosed environment that is decoupled from the general environment [17]. However, the research on epidemic risk management around the world still needs to be strengthened [18]. Wang et al. (2020) discussed the risk management measures of COVID-19 in Chinese universities [19]. McAleer (2020) concluded that prevention is better than cure for the COVID-19 epidemic [18]. The critical importance of diagnostic tests in emergency situations is determined [20]. It seems sensible to conduct more tests and target more patients, and meanwhile it is also necessary to consider the cost issue [18]. There is mounting evidence that patients with mild symptoms or even no symptoms can transmit the disease [21,22]. However, there are few papers on risk management from the perspective of cruise ships. Chinese scholars Liu and Zhang, taking COVID-19 as an example, propose short-term countermeasures and long-term epidemic prevention mechanisms for cruise ships [2]. At present, the research on risk management of cruise ship diseases is still worth discussing.

Tracking and reviewing the evolution of knowledge and trends allows us to understand the past, analyze the present and anticipate the future [23,24]. To that end, this study aims to comprehensively analyze the global references related to cruise diseases in the WOS database from 1996 to 2019. Specifically, this systematic review research intends to:

1) examine the trends of cruise diseases research;
2) analyze previous cruise diseases studies in terms of study contexts, organizations, authorship status, and keywords;
3) explore the themes of cruise diseases research over the last 24 decades;
4) present the factors of cruise diseases risk management, propose a framework of cruise diseases risk management and provide reference for in-depth research.

2. Methodology and data sources
2.1. Methodology

The developments of information technology and bibliometrics have provided the basis for generating visual software [25,26]. This paper chooses VOSviewer 1.6.10, ArcGIS 10.6, UCINET 6 as measurement and visualization software, and chooses STATA and Excel as auxiliary measurement tools [26]. This method enabled us to identify current profitable countries, authors, co-cited references, keywords and other information, so as to summarize the current status and results of previous research.

2.2. Data sources

The source of literature data is Web of Science Core Collection. The WOS Core Collection is a collection of authoritative and influential academic journals from around the world, covering a wide range of disciplines, and is characterized by high quality, large quantity and time span, and complete documentation [27]. The data retrieval is carried out by using the fields of "TI = cruise ship*cruise line*illness*epidemic*", etc. In order to ensure the representativeness of documents, set "Document Types = ARTICLE OR REVIEW" to refine, remove articles unrelated to cruise diseases, and finally obtain 69 valid documents between 1996 and 2019. The above search was conducted before January 1, 2020.

A list of 437 documents that meet the search criteria [TI = cruise ship*cruise*, etc. AND TS = cruise ship*cruise*, etc.] between 1996 and 2019 was obtained according to the above operations. Extracting keywords and listing the top 10 keywords with high frequency and strong centrality (Table 1), we found that disease outbreak is one of the top ten keywords in the cruise field, but the number of valid documents is only 69, accounting for 16% of the total number of valid articles, indicating that the number of documents in the field of cruise diseases is small and the research attention is not high.

3. Characteristics of literature publication and authors
3.1. Publication trend

Fig. 1 shows a regression model of the number of publications from 1996 to 2019 using the STATA software. The model shows that the number of articles published in the field of cruise diseases has not increased significantly, and the time series of articles published in WOS has been adjusted by 17.39%. In addition, the scattered points on the graph show that the number of published articles is highly volatile, with the highest value of 6 articles / year and the lowest value of 0 articles / year, and the average annual number of articles is less than 5, indicating that most scholars pay little attention to cruise diseases.

3.2. Publication output

In order to quickly identify publications with higher contributions, Table 2 lists the top 10 source titles, organizations, authors and countries of 69 publications.

In Table 2, the organizations with a total percentage of 3% are Atlanta Res Educ Fdn, Chinese center for disease control prevention, European Centre for Disease Prevention Control, Instituto Adolfo Lutz, Minis Hlth, Netherlands National Institute for Public Health and the Environment, Purdue University and University of Zurich.

Table 1

| Ranking | Keywords          | Frequency | Ranking | Keywords          | Centrality |
|---------|-------------------|-----------|---------|-------------------|------------|
| 1       | cruise ship       | 97        | 1       | ship              | 0.43       |
| 2       | tourism           | 67        | 2       | emission          | 0.40       |
| 3       | cruise            | 61        | 3       | intention         | 0.37       |
| 4       | cruise satisfaction| 56        | 4       | flow              | 0.36       |
| 5       | model             | 55        | 5       | luxury cruise     | 0.24       |
| 6       | impact            | 39        | 6       | china             | 0.23       |
| 7       | experience        | 38        | 7       | impact            | 0.22       |
| 8       | port              | 30        | 8       | service           | 0.21       |
| 9       | passenger         | 29        | 9       | outbreak          | 0.20       |
| 10      | outbreak          | 22        | 10      | disease           | 0.20       |
3.3. Regional distribution of publications

A total of 396 authors published articles in 21 countries between 1996 to 2019, with contributions ranging from 36 articles (52.0%) to 1 article (1%). With regard to the regional distribution of research publications (Fig. 2), Europe becomes the leading region of cruise diseases research constituting 42.7% followed by North America 38.8% and Asia and the Australasia 5.8%. South America obtains only 2.9% of the entire research outcomes. There is no cruise diseases research documented both in Africa and the Middle East. This is related to the market phenomenon of the global cruise industry. Europe is the second leading cruise destination of the world next to North America, and Italy and the UK are the leading cruise ship destinations in Europe [28]. On the other hand, Asia and Australasia are the most rapidly growing cruise destinations of the globe [28].

3.4. The intensity of organizational collaboration

The Table 3 records the top 4 organizations in terms of total link strength. The total link strength of the organization is not related to the number of documents and citations, and is connected to the cooperation groups. From 1996–2019, there were 150 organizations involved in cruise ship disease research. However, only a small number of organizations where the links exist are shown on Fig. 3a. Fig. 3b shows the organizations with more than 2 research records in this field in the WOS.

Table 2
Top 10 more productive sources, organization and countries among 69 publications.

| Ranking | Source Titles                              | Organizations-Enhanced | Authors | Countries |
|---------|-------------------------------------------|------------------------|---------|-----------|
|         | Source Titles                              | Organizations          | TP      |           |
| Top 1   | Journal of travel medicine                | Centers for disease control prevention USA | 26%     | USA       |
| Top 2   | Emerging infectious diseases              | University of Thessaly | 9%      | England   |
| Top 3   | Clinical infectious diseases              | Health protection agency | 7%      | Italy     |
| Top 4   | Epidemiology and infection                | Istituto Superiore di Sanita | 6%      | Greece    |
| Top 5   | Eurosurveillance                          | National Kapodistrian  | 6%      | Australia |
| Top 6   | Food and environmental virology           | Cleveland clinic foundation | 4%      | Germany   |
| Top 7   | American journal of preventive medicine   | Robert Koch institute   | 3%      | Peoples r china |
| Top 8   | Annals of emergency medicine              | University of California system | 3%      | Canada    |
| Top 9   | Bmc public health                          | Atlanta Res Educ Fdn    | 3%      | Brazil    |
| Top 10  | Journal of infectious diseases/Travel medicine and infectious disease | Chinese center for disease control prevention, etc | 3%      | Denmark/France/Luxembourg/Netherlands/Sweden/Switzerland |

a ST: source titles;  
b TP: total percentage;  
c both 3%

Fig. 2. Global cruise disease research productivity contribution.
There are only three organizational collaboration groups and the largest group is composed of five members, including the University of Thessaly in Greece, the British Health Protection Agency, the Robert Koch Institute in Germany, etc. Among them, the University of Thessaly in Greece is more central. The subsequent cooperation is carried out by 1–2 members, the map node composition is loose, and the intensity of cooperation between organizations in this field is relatively low.

3.5. Analysis of prolific authors

To identify prolific authors, the square root of the total number of authors (396) was calculated according to Price’s (1976) law and got the value 19.90 [29]. Initially, the 20 most productive authors were considered. However, the number of articles published by the 20th author to the 32nd author is 2, and there are great similarities in the scientific research of cruise diseases, so the top 32 authors were selected [30]. The contributions of the 32 authors range from 2 to 7 articles, which isolated them from other researchers with a yield of 1 article in the WOS database [30]. The number of articles was reduced from 79 to 36 through author co-signatures.

Only connected nodes are displayed on the map. In Fig. 4c, the authors whose total link strength is more prominent are Harris J, Nichols G, and Hadjidjristodouli C. These three authors co-exist in a prolific author cooperation network (Fig. 4a). Fig. 4a and b are visual maps of the prolific author network, both made up of 6 members. Among them, Nichols, Gordon and Fromkin, Kenneth have the closest relationship with the other 5 authors. The author group centered on Fromkin, Kenneth (Fig. 4b) has a relatively stable structure, and the cooperation intensity is higher than that of the author group centered on Nichols, Gordon (Fig. 4a). In addition, there are multiple authors who lack contact. Overall, the intensity of collaboration among prolific authors is relatively low.

If the documents published in 2014–2019 are regarded as contemporary work, there are only 12 contemporary authors among the 32 prolific authors (Fig. 5). After screening, the initial identification of 36 documents were reduced to 6 documents (which are contemporary) [30], which accounted for only 9% of the total. The research scope of these articles is only four countries: the United States, Italy, Brazil, Sweden.

4. Research contents and hotspots

4.1. Classification of research contents

Currently, the literature on cruise diseases research covers 19 categories of WOS (Fig. 6), of which the top five are infectious diseases, accounting for 52.2%; public environmental occupational health, accounting for 43.5%; medicine general internal, accounting for 24.6%; immunology, accounting for 18.84%; microbiology, accounting for 17.4%.

4.2. Themes and hotspots of cruise diseases research

Since keywords are a precise summary of the literature, analyzing high-frequency keywords can directly reflect the subject content and hot issues in the academic field [31]. Bibliometric data shows that this research involves a total of 239 keywords. The time change of the keywords from 1996 (dark blue) to 2019 (dark red) is shown in colour (Fig. 7a). As shown in Fig. 8a, cruise disease research is mainly concentrated in 2010–2015. In each research sub-field, there are frequently occurring keys such as epidemiology, outbreak, transmission, passenger and so on.

The co-occurrence threshold of keywords is set to 3, and 22 keywords are introduced into the visual analysis. VOSviewer 1.6.1 automatically divides the extracted keywords into 5 clusters (Fig. 7b), which are represented by different colors. Circles of the same color indicate similar themes. As shown in Fig. 8b, the keywords with larger circles are

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### Table 3

Top 4 organizations in terms of total link strength.

| Organizations                        | Documents | Citations | Total link strength |
|--------------------------------------|-----------|-----------|--------------------|
| HLTH PROTECT AGCY                     | 3         | 121       | 20                 |
| CTR DIS CONTROL & PREVENT            | 14        | 554       | 19                 |
| ROBERT KOTH INST                     | 3         | 102       | 18                 |
| UNVI THESSALY                        | 6         | 54        | 18                 |

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![Fig. 3. Organizational cooperation network in cruise disease research. Note: (a) network visualization of 150 organizations based on total link strength; (b) network visualization with a record ≥ 2 in WOS.](image-url)
outbreak, gastroenteritis, norovirus, cruise ship, transmission, passenger behaviors. The close distance between these keywords shows similar research themes.

Based on the analysis of the keyword network, Table 4 summarizes the research themes of cruise disease. Norovirus, respiratory diseases, Legionnaires’ disease and vaccine-preventable diseases account for a large proportion of these research themes (Fig. 8).

Norovirus is a common cause of outbreaks of acute gastroenteritis and diarrhea in cruise ships. It spreads among the crowd through food, person-to-person contacts, etc., even if sanitary treatment has been carried out on board ships, new strains of the virus strain can still be created and spread on land [32]. By quantifying the environment in which norovirus is transmitted, examining the factors that contribute to outbreaks, the relative impact of direct transmission, and passenger behavior, scholars have found that environmental transmission triggers a series of epidemics, but that direct transmission dominates [33–35]. Scholars have also found that vigorous promotion of good hand-washing habits can prevent or reduce outbreaks of disease; isolating sick passengers and cleanliness are beneficial, but they do not seem to be so effective in controlling the epidemic [35,36].

Respiratory diseases are common infections on cruise ships, including and influenza A (H1N1, H3N2), influenza B other diseases [37,38]. Reviewing the flu cases on cruise ships, it is found that influenza can spread widely during outbreaks of cruise ship activities and occur outside of the traditional flu season [39]. Individuals in crew cabins and restaurants faced the highest infection risk [38]. The risk of infection can be reduced to some extent by increasing the ventilation rate in some or all locations [38]. The use of high efficiency particulate air filters and ultraviolet germicidal irradiators in the ventilation system is the most effective measure [38]. In addition, implementing a comprehensive epidemic prevention and control plan, including timely antiviral treatment, may reduce the rate impact of influenza infection on cruise passengers [39–41].

The increasing incidence of legionellosis among cruise passengers is related to water supply systems [42], especially in closed and crowded environments. Legionella readily survives and multiplies in water pipes and spreads into the environment through air conditioning systems and water distribution points [43]. Chemical, physical and bacteriological analysis of water samples collected from key locations (crew compartments, kitchens, coffee bars, rooms with central air conditioning...
systems, and etc.) revealed that nearly half of the area was contaminated by Legionella, concentrated in showers and hand basins [44]. Therefore, some scholars have put forward a water safety plan to apply water treatment systems to ship water supply systems, including drinking water, recreational water facilities, decorative water facilities and fountains, which is expected to improve ship water management and thus reduce the incidence of diseases [45].

The international composition of the ship’s population and the enclosed environment are conducive to the spread of vaccine-preventable diseases such as measles, rubella and chickenpox among passengers [46]. A review of these cases reveals that most varicella patients are crew members [47]. These crew members are usually from tropical areas where varicella immunity was acquired in childhood or early adulthood, or no varicella vaccination program [47]. Cruise lines should ensure that crew members are immune to these diseases [48], and should consider whether it is a cost-effective option to screen crew members for varicella, measles and other diseases and vaccinate them before placement [47,48].

In addition to the above four categories, passengers on board may also suffer from motion sickness, cardiovascular, hepatitis E and other diseases [49–51]. Research on the patterns and characteristics of injuries and illnesses on polar cruises is conducive to the formation of more standardized medical facilities and personnel training guidelines, thereby improving the quality of life on cruises [49].

In the current epidemic, the Diamond Princess cruise is a study case of the spread of COVID-19. The related research mainly focuses on the clinical characteristics of COVID-19, epidemiological investigations, and descriptive studies of the COVID-19 epidemic among passengers and crew [52–54]. The results show that COVID-19 can be transmitted by droplets, contacts, aerosols and “fecal-mouth” [2]. Estimating the number of novel coronaviruses breeding on cruise ships, it is found that the characteristics of cruise ships have clearly magnified the potential for disease transmission [55]. Isolation, rapid and comprehensive detection of infection play an important role in controlling the epidemic [13]. The Princess Cruises, which landed in Taiwan, has effectively reduced the infection and death rates among cruise passengers through the application of big data analysis technology [56].

Based on the above analysis, Table 5 summarizes the types and prevention and control measures of cruise diseases.

### 4.3. Influencing factors of cruise disease prevention and control

Fig. 9 summarizes the prevention and control management factors in the research on cruise diseases transmission methods and prevention and control measures. The factors include the port country’s epidemic prevention capacity, the mode of disease transmission, the relevant regulations on international public health disposal, the design and construction of cruise ships, the medical and health conditions on cruise ships, and the characteristics of cruise tourism activities.
7. The design and construction of cruise ships

The main route of transmission of COVID-19 on cruise ships is considered to be person-to-person transmission, but other routes should not be overlooked, such as aerosol transmission via central air supply or drainage systems [59]. Inappropriate use of heating, ventilation, and air conditioning (HVAC) systems on cruise ships can lead to the spread of disease [5], and confined environment allows for higher rates of diseases transmission [60, 61]. The design of sanitary piping systems and waste disposal discharges on cruise ships also increase the likelihood of disease transmission [62].

4.3.5. The medical and health conditions on cruise ships

Medical facilities and staff on cruise ships need to have a higher level of service due to the aging passengers and the isolation of the environment [63]. After the outbreak of the epidemic on the Diamond Princess, due to the lack of medical and health facilities, non-traditional quarantine measures such as classified isolation and batch transfer were not taken in time [2]. Instead, centralized quarantine measures were adopted, which did not meet the characteristics of the spread of the epidemic and increased the potential risk of infection for larger confined spaces.

4.3.6. The characteristics of cruise tourism activities

The special feature of the cruise ship is that it is an isolated system, with diverse people on board, strong mobility, and a high concentration of population in a limited space, which shortens social distance and provides very favorable conditions for the spread of the virus [11]. Cruise travel has aggravated the spread of diseases to a certain extent. The cruise ship sails in various locations, and the origin or destination is rich in tourism activities, which enables passengers to have a large area of contact with the local community.

5. Conclusion and recommendations

5.1. Conclusion

The COVID-19 pandemic has had a profound impact on international tourism and cruise industry. In this context, the analysis in this paper attempts to provide a critical perspective for the scientific research involved in cruise disease. The current research analyzed 437 articles in the cruise field and 69 articles in the cruise diseases field. The study results show a significant increase in articles published in the cruise field from 1996 to 2019, with “disease outbreaks” being one of the top ten keywords. In contrast, cruise disease research has a low number of publications, with an average annual publication volume of less than five articles. Scholars pay little attention to them, with fewer cooperative research groups.

The countries with high global productivity in cruise disease are, in turn, the United States, the United Kingdom, and Italy. This is linked to the market of the global cruise industry. Research results in this field are highly concentrated and relatively discrete globally, with a few countries/regions possessing the majority of published research results. There are few cooperative groups between prolific authors and organizations, and the overall intensity of collaboration was low. Since the

| Table 4 |
|-------------------------------------------------|
| Research themes on cruise diseases.            |
| Primary themes | Secondary themes | Tertiary themes |
|----------------|------------------|----------------|
| Norovirus (gastroenteritis, diarrhea, stomach upset, etc.) | Epidemiological research | Incidence rate, time, location, characteristics of infected population, etc. |
|                  | Source-based investigations | Foodborne pollution, point source pollution, waterborne pollution |
| Disease transmission research | Outbreak environment and means of transmission | Impact of direct transmission |
| Passenger behavior research | Early awareness of virus perception | Passenger behavior and virus transmission during the outbreak |
| The effectiveness of passengers’ willingness to wash their hands |
| Respiratory diseases (influenza A (H1N1, H1N2), influenza B, etc.) | Epidemiological research | Incidence rate, time, location, characteristics of infected population, etc. |
| Degree and method of transmission | Airborne transmission and indoor social networks |
| Prevention & Response | Disease/health surveillance and vaccine effectiveness research |
| Legionnaires’ disease | Epidemiological research | Incidence rate, time, location, characteristics of infected population, etc. |
| Source of infection | Water supply system, central air conditioning system, pool, etc. |
| Influenza | Clinical and public health |
| Prevention tool | Water safety management and planning |
| Vaccine-preventable diseases (measles, rubella and chickenpox, etc) | Epidemiological research | Incidence rate, time, location, characteristics of infected population, etc. |
| Management and control | Investigation of contacts and vaccinators |
| Injuries and illnesses on polar cruise | Patterns & Characteristics | Incidence rate, time, location, characteristics of infected population, etc. |
| Other themes | Medical facility hygiene and health care information for travelers |
| Impact on health protection in onshore communities |
| Research on motion sickness, cardiovascular, hepatitis E and other diseases |

4.3.1. Port country’s epidemic prevention capacity

The sudden mass epidemic on cruise ships is a challenge for every port state. As an important link between cruise ships and port destinations, ports play a crucial role in epidemic prevention and control. The cruise ship sails in various locations, and the origin or destination is rich in tourism activities, which enables passengers to have a large area of contact with the local community.

4.3.2. The mode of disease transmission

It can be seen from Table 4 that the main mode of disease transmission on cruise ships is respiratory infections caused by droplets or aerosols, and pathogens are excreted with excrement from patients or carriers, and contaminate hands, water, food and utensils through domestic contact. Infections can be summarized as droplets, contact, aerosols, and “fecal-oral” transmission.

4.3.3. The relevant regulations on international public health disposal

Different from river cruise ships and regular passenger ships, which are generally of national origin, more than 60% of the world’s cruise ships fly Flags of Convenience for ease of navigation and management [58]. The Diamond Princess’s emergency response to the COVID-19 outbreak highlighted the complexity of handling international public health incidents on cruise ships, and it is reflected in the division of responsibilities between the flag state and the port state, as well as the different nationalities of the ship’s operators, crew and passengers [2]. It is also a test of relevant international public health laws, reflecting the serious deficiencies in the prevention, detection and response to health emergencies at the national level, and it does not meet the requirements of international regulations [18].

5. Conclusion and recommendations

5.1. Conclusion

...
outbreak of COVID-19 epidemic, scholars have gradually paid more attention to the field of cruise diseases, and the intensity of collaboration between authors and organizations is gradually increasing.

Cruise diseases research is mainly concerned with epidemiology, occupational health in the public environment, internal medicine, immunology and microbiology. The research area not only focuses on disease prevention and health protection, but also extends to other fields like ecology, architecture, sports, leisure tourism, etc.

From 1996–2019, the hot themes of cruise disease research are norovirus, respiratory diseases, Legionnaires’ disease, measles, rubella, chickenpox; COVID-19. The branch of research in norovirus on cruise ships is even richer. COVID-19 is currently a relatively active research topic. Passenger behavior is more striking in Fig. 7, but in the research hot spot, the focus is on the characteristics of the infected population rather than the passenger behavior during the disease outbreak. Injury and illness researches on polar cruises account for only 6% of the total, which may be related to the fact that there were fewer polar cruise itineraries in the past. There may be a link between the level of health-care facilities on cruise ships and the spread of disease. The transfer of people infected with diseases on cruise ships will affect the health protection of local communities. Further more, no other cruise ship disease has had such a huge impact on global health protection as COVID-19, which also requires the prevention of pandemics in international policies and regulations to be strengthened.

The diversity of disease transmission modes, the characteristics of cruise tourism activities and the complexity of dealing with international public health events increase the difficulty of managing disease prevention and control on cruise ships, placing higher demands on port state epidemic prevention capabilities, cruise ship design and construction and medical and health conditions.

To sum up, there are still some neglected but worthwhile research themes in cruise disease:

a) Researches on passenger behavior during cruise ship diseases outbreak.

b) Epidemiological researches of polar cruise.

c) Researches on the relationship between the level of medical facilities and staff training on cruise ships and disease transmission.

| Type                  | Disease                          | Mode of transmission                                                                 | Prevention and control measures in the cruise environment                                                                 |
|-----------------------|----------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| Infectious diseases   | Gastrointestinal transmission    | The pathogens are excreted from the body of the patient or carrier, and infected by eating into the body by contaminating hands, water, food and utensils through daily contact | Isolation of the source of infection; Hygienic management of food and water on cruise ships; Medical facilities and first aid capabilities on the cruise ship |
| Respiratory transmission | Influenza A; Influenza B; Legionnaires’ disease; measles, rubella, chickenpox; COVID-19 | The pathogens invade from human respiratory tract infections such as the nasal cavity, throat, trachea and bronchus; The pathogens are excreted from the body of the patient or carrier, and infected by eating into the body by contaminating hands, water, food and utensils through daily contact | Isolation of the source of infection; Increasing the ventilation rate of the place; Medical facilities and first aid capabilities on the cruise ship |
| Non-communicable diseases | Cruise transportation triggers | Motion sickness                                                                      | --                                                                                                                       |
| Others                | E.g. cardiovascular              | --                                                                                   | Medical facilities and first aid capabilities on the cruise ship |

Table 5: Types of cruise diseases and prevention and control measures.

Fig. 9. Factors of cruise diseases prevention and control management.
d) Researches on the relationship between cruise diseases and local community health protection.
e) Researches on the role of policies and regulations in cruise disease prevention.

In addition, from Table 1 and Fig. 7b, it can be seen that the hot keywords in the cruise research lack risk management. The research on cruise diseases is mainly focused on one disease, and lacks systematic research on disease risk management. On the basis of existing and available literature, in the discussion section, we put forward and summarize the influencing factors of cruise disease risk management and construct a risk management framework to provide reference for the sustainable development of cruise industry.

5.2. Recommendations

5.2.1. Timeline of the cruise disease risk management process

It is far from enough to rely solely on vaccine development to fight various infectious diseases [64]. There is an urgent need for a more effective "active prevention and control" approach to rapidly prevent and stop the spread of new infectious diseases and to keep the spread of such diseases to a minimum until they are eradicated [64]. According to the "Research Report on Restart of Chinese Cruise Industry ", the risk of cruise disease can be summarized in the following three keys [17]: a) the risk of viruses boarding the ship; b) the risk of virus transmission on board the ship; c) the method to control the spread of the disease after contracting the virus. Given the uniqueness of international cruise ships and the characteristics of disease transmission, a systematic and comprehensive disease risk management framework for cruise ships should be established, with the timeline as the baseline, and a reasonable cruise ship disease risk management process can be formed (Fig. 10).

Before arriving at the port, the destination, cruise passengers and crew are subjected to an epidemiological investigation. Cruise lines should deny boarding to people with questionable survey results and change questionable destinations to intercept the source of infection and prevent the spread of the virus in a timely manner.

After arriving at the port, the port department should conduct a health screening on the personnel, and only healthy personnel can board the ship. The disinfection of baggage requires an independent dynamic operation line to avoid cross-infection.

During normal sailing, cruise passengers and crew need to conduct real-time health tests. Once a disease infection event occurs, the staff should immediately check the epidemic, determine the source of the infection, conduct zoning isolation, and report the situation to the superior or the next port. When returning to the port, the cruise line and port authorities should make use of the ship-port synergy to effectively organize the disembarkation of people in groups.

5.2.2. Risk management framework

The "Community Capacity" component of Health Emergencies and Disaster Risk Management (Health-EDRM), developed by the World Health Organization, emphasizes the importance of local participation in addressing health risks in emergencies [65]. Cruise ships, known as "marine mobile community", are more prone to mass outbreaks of disease than communities on land [66], so it is important to establish a "maritime mobile community prevention and control system" (Fig. 11).

Firstly, cruise lines can add a central disease command center on board, which is designed to respond quickly to large-scale outbreaks and act as a nerve center to mobilize resources and coordinate personnel. Secondly, we continue to deepen our cooperation with governmental and non-governmental organizations to promote the application of science and technology in cruise disease risk management and to develop health regulations for cruise ships that are above international standards. For example, through cooperation with EcoloxTech, Norwegian Cruise Line has enabled its 28 cruise ships to have a new disinfection technology- HOCl technology, which is safe and highly toxic. In cooperation with the world’s leading medical experts and the US Centers for Disease Control and Prevention (CDC), strict health and safety cruise measures have been formulated for each cruise ship, with health regulations far exceeding national standards [67].

The influence of cruise design and construction on disease prevention and control management cannot be ignored. This has given rise to a new topic how to design an "immune" ship, the so-called prevention...
through design (PtD). This paradigm is advocated by the National Institute of Occupational Safety and Health in the United States [68]. PtD technology can be applied in the process of vessel design, construction and modification [68]. The PtD method can be used to control the capacity of a cruise ship, thus allowing the implementation of a social distance criterion. Architects and engineers may consider redesigning shared spaces to accommodate fewer people and increase personal space. If the danger cannot be eliminated or replaced, engineering can be the preferred control method. For example, HVAC systems with both HEPA filters and ultraviolet germicidal (UVGI) devices should be the primary combined control measure, as well as increasing the airflow from the HVAC system to the dining rooms, where the risk of infection is higher, could also be an effective control measure [69]. Engineering controls such as these can be implemented at any stage of the ship construction, including retrofitting existing ships’ water treatment systems, sanitary plumbing systems and waste disposal systems.

In view of the medical and health conditions of cruise ships, cruise lines need to devote themselves to the improvement of basic medical facilities. Cruise lines should pay more attention to medical services and links to cruise health websites [63]. In addition, the upgrading of medical facilities on cruise ships and the implementation of active telemedicine conferences are alternative methods of air evacuation that need to be studied [70]. In addition, every cruise ship should be equipped with medical isolation facilities. On 14 September 2020, a new Negative Pressure Isolation room was opened at the Tianjin Cruise Terminal in China, which is an important isolation medical facility for the prevention of serious outbreaks of infectious diseases by controlling the source of infection and cutting off the transmission route [71].

Raising public awareness of disease is necessary to control an ongoing epidemic [72]. This is also an important means to reduce the difficulty of cruise risk management due to the diversity of disease transmission methods. In addition to increasing the social distance of passengers, cruise disease command center should mobilize people to take self-reinforcing preventive measures, including washing hands frequently, wearing masks, avoiding cold and raw food, and repeated testing. In addition, Taiwan’s national health insurance system played an important role in the epidemic [73]. Cruise lines and the governments of countries such as flag states, tourists and staff should implement a universal health insurance system.

It is important to establish a "maritime mobile community prevention and control system". Based on the research on cruise diseases by scholars from 1996 to 2019, combined with the influencing factors of cruise disease prevention and control, the risk management framework of cruise diseases is summarized as Fig. 12.

The big data analysis techniques, government initiatives, and collaborative governance model applied by Taiwan, China in response to the COVID-19 pandemic are used for reference [56,73]. Of course, it is particularly important for cruise disease risk management to reduce the complexity of dealing with international public health events. This requires the joint participation of multiple entities to form a long-term and effective cooperation mechanism, thus avoiding systemic failures in the understanding of the pandemic by the cruise industry management [74]. Major stakeholders in the cruise industry, including trade groups, industry leaders, infection control experts, and government and non-governmental organizations, can work together to develop a broader contingency plan to ensure effective outbreak response on board and shore assistance at ports [68]. For example, all parties actively cooperate with mask manufacturers to ensure the supply and distribution of masks [73].

For the port epidemic prevention department, it is necessary to fully study the main risks of various infectious diseases on international cruise ships, find out the key points of risk control, and establish a systematic and complete international cruise epidemic prevention and control system [2]. In practice, the functions of multi-departmental joint prevention and control should also be brought into play, and large-scale personnel transfer and rescue exercises should be designed to improve the port’s crisis management capabilities. Port authorities should do a good job in “zero infection” of employees and disinfection of luggage-/materials by implementing border control and isolation measures, carrying out all-round and multi-means detection measures for tourists, isolating infected tourists and transfer them to hospitals for treatment in time. At the same time, port state governments could establish “temporary cabin hospitals” in ports where cruise ships stop or nearby islands to deal with mass disease outbreaks and to avoid problem of insufficient resources [2].

It is widely accepted that both "transparency" and "authority" are necessary in the battle against COVID-19 [73]. Big data analysis allows not only the tracking of disease transmission routes and close contact surveys, but also epidemiological investigations of people and destinations [64]. Cruise lines should work to form cooperative mechanisms with governmental and non-governmental organizations in various countries on disease prevention and control, and to form a team of senior experts in data analysis, medical practice and research, public health, infectious diseases, biosecurity, and maritime operations, among others, to build a cruise health line data platform to monitor travelers’ whereabouts and health in real time. A health code or electronic health card is
formed through a big data platform, making the system a tool to help track citizens’ health status and whereabouts [73].

Conflict of Interest

The authors declare that they have no conflict of interest.

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