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Mapping the knowledge base for maritime health: 2. a framework for analysis

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ABSTRACT

The knowledge base for maritime health has a number of constant features that have become apparent over the last 150 years. These can be used to structure an analysis of the current state of knowledge and to identify where there is sound evidence about the nature and scale of risks and about the effectiveness of intervention to reduce harm. It can also show where there are deficiencies in knowledge and point to the ways in which these could be remedied. Past events, as discussed in the first article, also indicate the dynamics of the political, economic and human interactions that are central to improving knowledge and to its application to improve the health of seafarers.

The sources of useful knowledge about seafarer's health range from single case reports of an unusual disease to long-term studies of common chronic disease incidence. The most accessible events to record are clinically apparent illness, injury, or cause of death, but active investigative studies may look at risks in the environment, personal risk factors, or pre-clinical phases of disease.

Comparisons between subsets of a population are needed to look rigorously at health risks or at the effectiveness of intervention. This is best done if information on the at risk population can be used as the basis for deriving the incidence or prevalence of illness and if the populations compared are as similar as possible in every way, except that being studied. Sometimes large studies in onshore populations can provide information that it is not feasible to collect on seafarers.

Information on seafarers' health can be collected in several settings: at sea, on arrival in port, during leave periods, or after retirement. For acute illness and for injury a single setting can provide the basis for estimating risks, but for chronic conditions cases arising in several settings have to be included and the at risk population calculated to enable the incidence to be studied.

Knowledge about the health of seafarers can be used to improve prevention both by attention to the conditions of living and working at sea and by selection of seafarers who are considered 'fit' for work. It is also important for defining the needs for emergency care at sea and in port. The overall patterns of illness and injury in seafarers and how these compare with other workers are important inputs to regulatory decisions on the measures to be taken to reduce harm from illness and injury. Markers of improved seafarer health can confirm the effectiveness of measures taken with this goal in mind.

Reducing the contribution of health-related impairment to accidents and other risks at sea requires knowledge of the effects of such impairments on performance and safety in the routine and emergency tasks of a seafarer. This information can then be used to determine whether someone with an impairment can safely work at sea.

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Key words: maritime, seafarer, seaman, health, disease, fitness, capability, work, epidemiology, risk, intervention

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INTRODUCTION

The historical review in the first article demonstrates many of the components of the knowledge base for maritime health. As it uses information from the past it also provides insights about the effectiveness with which such knowledge has been used. It indicates that, while scientific and professional skills were needed to develop the knowledge base, the support and funding needs for all but the simplest investigations depended on decisions taken by regulatory, political, and economic interests. Both the actual costs of investigations and the potential costs and benefits of any intervention found to be necessary as a result of them played a part in deciding whether to fund investigations.

The first article used the history from a single flag state as an example. This one will develop a framework using this analysis that can be used more widely to review the state of knowledge on risks, the extent to which interventions have been validated, and the gaps in our understanding of both risks and interventions. It will also use historical examples to look at the contrasts between the perspectives of ship owners and their agents, seafarers and their trade unions, and regulatory bodies and their political masters, noting how these influenced decisions on data collection and analysis and guided interventions to improve the health of seafarers. It will go beyond the historical review and consider some more recent changes in approaches to seafarer health.

TYPES OF INFORMATION RELEVANT TO SEAFARER HEALTH

Well-established epidemiological principles determine the validity of the knowledge base on seafarer health. These have often been ignored in discussions about the interpretation of maritime health investigations, but they are key to an appraisal of the current state of knowledge.

There are a limited number of types of information about seafarers' health that can be used to develop a knowledge base on risks and on the effectiveness of interventions. Studies which have used standardised definitions, notable agreed diagnostic criteria, to identify cases will be less liable to personal observer biases and so will provide a more valid estimate of risk. In particular, presumptions about disease frequency or its implications that are based on the memories of those concerned with clinical care are likely to be biased by clearer memories of the unusual or of cases that caused particular problems in diagnosis or management.

Knowledge may be derived from diagnostic information collected in the course of medical care. Simple collections of case data, however well standardized, will only provide information about the relative frequency of different types of condition, although for rare diseases this in itself may be sufficient to indicate the need for action and to show whether intervention has been effective. Case series may be biased by decisions about which health care provider to visit for clinical care. They cannot be used to estimate the overall risk in a population of seafarers. Comparisons between different groups of people are the basis for determining whether risks differ. Case series do not enable such estimates to be made reliably, other than as time trends in the relative frequencies of different conditions over a period of time in a similar population, as noted for scurvy in the 1860s.

In order to provide quantitative estimates of risk in a population of seafarers it is essential to have not only information on cases but also reliable estimates of the population from which the case data comes. This is not easy to obtain for seafarers who spend their time divided between sea, ports, and leave. Information on the population at risk allows either the prevalence rate, that is the percentage of people with a condition at a fixed point, or the incidence, that is the frequency of new cases per unit of population over a fixed time period, to be calculated. These measures can be used to make comparisons of risk between different groups of seafarers, subject to corrections for factors such as age, gender, and ethnicity.

Knowledge about the relative frequencies of disease or injury from case series or risk estimates from prevalence or incidence studies are specific to the settings in which the data were collected. Thus, while a count of cases and assessment of their frequency at sea or in seafarers referred for onshore medical care can be made it will only reflect the frequency in this setting. This can be useful in guiding requirements for treatment in the setting in which the information was collected or for considering preventative measures, especially for acute events such as accidents, but it will not reflect the totality of risk in a population that moves between work at sea, time in port, and leave periods. It is of little value in determining the patterns of risk from chronic or long latency conditions, whether they are associated with working and living at sea or have unrelated causes.

To quantify the risks from long-term conditions integrated case information is needed from several settings as well as an estimate of the population that encompasses those on sea service, those on leave, and those who have worked as seafarers but no longer do so. Active seafarers are a selected group, who may differ from the general population because those with conditions that could pose risks at sea have been excluded. They are also a survivor population, with those who do not wish to work at sea and those who become unfit to do so leaving this population, but possibly carrying long-term risks from their time at sea with

them. Leavers are an especially important group because they may well have a condition of interest to the investigator that has itself played a part in determining the decision not to continue working at sea. To get a full picture the numbers and causes of death of those who have died will also be required.

Studies based on information derived from clinical care are essential for care planning and for disease prevention but, as discussed, have limitations. In many areas of science and medicine a well-conducted experimental study is seen as the most rigorous and reliable means of obtaining a definitive result. There are practical and ethical limitations to conducting experimental studies in occupational groups such as seafarers. Exceptions are functional studies, for instance on vision or fatigue. Natural experiments may provide a less rigorous but useful means of investigating risk, for instance by looking at the effects of differing voyage or watchkeeping patterns on crew illness. Comparisons of relative frequency, prevalence, or incidence in similar groups of seafarers at different times may provide information both on the importance of a risk in different settings and on the effectiveness of any interventions that have taken place in the meantime.

Investigators may also use pre-disease measures to detect adverse effects or risk factors for future illness, for instance excess uptake of toxic substances, biochemical changes indicative of excess disease risk, or immune markers indicating the presence of latent infection or of an antibody response to it. In a similar way psychological states may be investigated using psychometric tests. Such methods are increasingly used in less controlled situations, for instance during seafarer medical examinations. When fully validated they can provide indications of risk and be used as a measure of the effectiveness of interventions. However, their use is beset by practical and ethical problems when their validity is less than perfect and the results are used to take decisions on individuals.

Given the difficulties in determining the frequency of disease or its incapacitating consequences in seafarers, an estimate of risk or of the likely benefits from intervention may be made using the better quality information that can be obtained from studies of other, often much larger, onshore populations and extrapolating these to seafarers. Care must be taken when doing so because of inherent differences between the population used and that to which the results are being extrapolated, for instance risks in seafarers may be reduced by medical selection processes or increased by the limited access to healthcare support whilst at sea. Extrapolation is most valid when prognostic aspects of disease are being considered, as the natural history of any condition is relatively constant when reviewed at population level. Predicting the links between health-related impairments and accidents by extrapolation from onshore occupational groups needs care because it requires detailed knowledge of job requirements. Sometimes it is, however, possible to find useful analogies in other modes of transport and in related tasks, for instance in the military or in process industry control rooms.

Whichever of the types of information described is collected its appropriateness will depend on the questions that it is being used to answer. Different data sources will be needed to look at the role of health-related impairment in maritime accidents and to investigate disease risks. For accidents the predictive indicators of risk and the circumstances of the incident and its outcome will be the variables. By contrast, that needed to determine the medications and the quantities required aboard a ship will relate just to disease and injury risks on board, while that needed to estimate long-term health risks has to be based on information about lifetime incidence (Table 1).

SETTINGS FOR THE COLLECTION OF INFORMATION ON THE HEALTH OF SEAFARERS

As noted, the way in which data on seafarer health is interpreted will depend on the setting in which it was collected. For short-term risks, and especially for injuries, the location at which they occur will be of great importance in identifying the interventions that can be used to reduce risks. For slowly developing long-term risks or those with a long latency period, for instance hearing loss from noise exposure or heart disease, a wider picture encompassing several settings is needed to determine disease frequency. However, even for long-term risks the location at which any acute illness occurs can be important in terms of the requirements for treatment or the acceptability of a person with that risk working in a situation where an acute illness or incapacitating incident can put themselves or others in danger (Table 2).

THE USES OF INFORMATION ON THE HEALTH OF SEAFARERS

While the collection and analysis of information on seafarers' health is largely a matter for health professionals, its use has implications for all parts of the maritime sector and this introduces a range of social, regulatory, political, economic, and ethical dimensions into all parts of the development of a knowledge base. The question of whose interest is it in to collect information must be addressed, and this largely depends on how it is to be used. Thus those who want to maximize the employment opportunities for their members may have a different view on the importance of the risk of an illness that may lead to evacuation and repatriation than

Table 1. Types of information relevant to seafarer health

1. Case reports: unusual events will be identified and specific problems with case management will be noted. Open to many biases depending on observer location, experience, and interests. A major way for new problems to be identified and failures to control known ones to become apparent.
2. Case series: a more structured basis for evaluating the relative frequency of different problems. Diagnostic criteria needed. Biased by the setting in which the series is compiled. Increased relative frequency in some diagnoses may reflect not a real increase but simply a reduction in others. Sufficiently valid to show excesses of rare diseases clearly, for instance scurvy, but not to give reliable information on more common conditions. Case series of incidents or accidents can provide a similar form of evaluation of relative frequency and may show the role of health-related impairments as contributors. For instance risks from colour vision defects.
3. Prevalence rates: information is needed on the population from which the cases come. Provide an absolute measure at a point in time, but rate depends on the duration of the condition. At sea this population may be the total number of crew/passengers on a ship, but onshore the difficulties in estimating the population of seafarers has been a major problem. Prevalence studies normally provide information about disease at a specific time (cross sectional)
4. Incidence rates: information on the total population is needed. The number of new cases is counted and the rate over a set time period is calculated. Death, because it has to be determined for legal as well as medical reasons has been the event most commonly studied. Incidence studies are inherently carried out over a period of time (longitudinal) and may be retrospective based on existing information available from records or prospective using records specially created by the investigators. The need to study chronic conditions such as pulmonary tuberculosis led to the collation of information from multiple sources to derive an estimate of the numbers of merchant seamen. This approach has not been used for widespread morbidity studies, and incidence studies on non-fatal illness have been limited.
5. Time trends: these can provide a natural experiment indicating changing patterns of disease or the effectiveness of intervention. Any of the above methods of study can show trends, but prevalence and incidence investigations will provide sounder information than anecdotal reports or case series.
6. Results of clinical tests: these include the vision and hearing assessments that are routinely performed, as well as those sometimes used such as physical capability assessments, spirometry, and biochemical or haematological investigations. Analyses may be presented either in terms of numbers, prevalence or incidence of abnormal values, or as quantitative data on numerical test values and their means and variability.
7. Experimental studies: true experiments are only acceptable for assessing functional performance, for instance visual capabilities. 'Natural experiments', taking advantage of different patterns of duty to study their consequences, can provide important information. Risk factors for disease, such as lifestyle indicators (e.g. smoking, exercise) or the results of clinical tests (biochemical, psychological, functional), are an increasingly important aspect of experimental studies as well as of screening programmes.
8. Extrapolation from other populations: the pattern of illness in seafarers may often be similar to that in the onshore populations from which they are drawn. These populations are both larger and easier to study. Results can be extrapolated to identify priorities for intervention in seafarers. Account must be taken of population differences and of different working conditions and lifestyles. Such extrapolation is particularly appropriate when treatment and prognosis are being considered as these largely depend on the inherent features of the disease rather than on the population being studied.

those who have to bear the costs of providing these services. At the same time, an individual, while accepting that they cannot work at sea if their vision is impaired to a level that means they can no longer act as a lookout, may feel that if they have heart disease that increases their risk of a myocardial infarction and of death at sea they should be free to decide for themselves whether they accept this risk and may resent being told that it is a reason for ceasing to work.

The historical review has indicated the limitations of the information about health risks that can be collected solely by an interested health professional, noting that more elaborate studies need to be organized and funded. This means that someone has to decide whether expenditure on a health investigation is likely to bring sufficient benefits to justify it and, more cynically, they may take account of the possibility that its results could lead to problems or expenditure that could be avoided by not supporting it. The circumstances identified in which investigation has been supported are largely those where it could not be avoided. Thus colour vision testing was studied when there was pressure from the officers' union supported by unresolvable cases that made the previous test methods unsustainable. Mortality studies were only funded when sustained pressure from a campaigner and the medical press about hidden tuberculosis risks in merchant seamen made it essential. Morbidity studies on malaria and on venereal disease were undertaken when these diseases caused crewing shortages under wartime conditions that had to be remedied.

All these investigations were state funded; none were funded by employers, trade unions, insurers, or other sectional interest groups. All these groups have at times either encouraged or discouraged investigations because of perceived benefits to or costs for their members, sometimes with results that surprised them. For instance employers

Table 2. Settings in which information on the health of seafarers is collected

1. Medical examinations prior to employment and embarkation: the prevalence and incidence of medical conditions can be calculated, using the total number of examinees as the denominator. Performance at functional tests such as those for vision and hearing can also be analysed. Results are biased as, after the first examination, they come from a pre-selected population. Those with serious health problems will not present for an examination to determine their fitness to continue work.
2. At sea: impairing illness or injury and deaths will be recorded. Apart from deaths these sources have rarely been used. Landing an ill seafarer in port may be recorded, both for legal reasons to enable repatriation and as part of clinical records. Since the 1920s records of radiomedical advice to ships have had the potential to provide an additional source of information and a few case series are available. They may be biased as they depend on the decision of the master to seek advice.
3. In port: hospitals and clinics have been an important source of case series on acute illness. Much of their caseload will be acute illness although ships, particularly those with surgeons, may also have records of those sent ashore for treatment. Services that arrange repatriations are another source.
4. Shore-based sources: seafarers may be identified by occupation in hospital records, on death certificates and on census returns. These sources can provide information on illness and death in those who are not currently working or who have retired. Biases include occupation from a subsequent onshore job being recorded and the lack of information on details of their work at sea. Social security and pension records: in some countries social security records contain details of sea service and of disabilities, while in others similar information may be available from pension funds.

tried to shift the debate on loss of life at sea from unseaworthy ships to unseaworthy seafarers in the 1860s but found that, while they were partly correct, their provision of low-cost, poor-quality lemon juice was a major contributor to illness. At a later stage officers' union unease about colour vision testing almost certainly led to a more satisfactory solution with tests introduced that were closer to the real-life tasks of lookouts.

The distinction between those health related impairments and conditions that can increase the risk of accidents and illness in others aboard and those which increase the risks to an individual from illness at sea or as a result of working at sea has been and is deeply rooted. In many jurisdictions different arms of government are involved while internationally the International Maritime Organization conventions cover the contribution of health-related impairment to safety, while those of the International Labour Office deal with illness at sea and the well-being of seafarers.

Several different sorts of information are collected in the course assessing the health of a seafarer. Some, like vision and hearing testing, look at relatively stable attributes that are relevant to reducing the risk of maritime accidents while others, such as a medical history of heart disease or epilepsy, are relevant both to accident reduction by reducing the risk of sudden incapacitation and to reducing the likelihood of illness occurring at sea. The ethical justification for taking decisions based on these results, where they are valid predictors of risk to others, is straightforward. Other medical conditions, such as the presence of a hernia, the existence of kidney or gallstones, or bad teeth, will not put a vessel at risk of an accident but will increase the liability of the seafarer to be unable to work or to need evacuation. Both create small potential risks to the vessel and to those who carry out evacuations but as the major risk is to the individual the ethics of exclusion from work, as opposed to giving advice on the need for treatment, are more equivocal. In all these situations the debate about what should be done can only be held in an informed way if there is a valid knowledge base about risks within which discussions can be grounded (Table 3).

DISCUSSION

The strength of using a historical perspective as the basis for this analysis of the components of the knowledge base for maritime health is that the consequences of changes to the knowledge and the ways in which different interests respond to them can be seen. Its weakness is that it will not reflect any changes that have taken place recently. Many features of the collection and analysis of data remain unchanged, for instance the settings in which data is collected and the basic scientific tools that are used to draw valid conclusions from the available information. The understanding of disease has changed, as have the methods for diagnosis and treatment – always a problem in looking at time trends, but not a new one.

Major changes to the world maritime industry mean that the possibilities for collection and analysis of information have altered, as have attitudes to the health of seafarers and to the willingness to investigate it and to take steps to use the information collected to reduce risks. Most of the knowledge that was accumulated prior to 1960 was from national fleets in the major maritime nations that were mainly crewed from those countries. As seafarers were drawn from the national population and returned to it on retirement follow up till death was possible, all records were held in a single country, and valid

Table 3. Uses of information on seafarer illness and accidents

1. To reduce risks at sea by selecting seafarers: information on patterns of illnesses and accidents at sea and data from onshore populations can help to shape the criteria used for determining fitness. Employers' concerns, which focus on the economic consequences of loss of a crew member and the costs of repatriation, can differ from those of maritime authorities who are concerned for maritime safety and sometimes for decent working condition or those of seafarers and their trade union representatives who are keen to maintain members in work.
2. To reduce harm from illness or injury at sea: includes specifying the content of training for officers in medical first aid and requirements for medications, medical equipment, facilities, and a medical guide, as well as the availability of radiomedical advice. The development of all these facilities has been incremental, sometimes based on studies of illness at sea, but more often on anecdotal information. Recommendations for change have usually been informed by developments in health care practice ashore rather than information gathered from seafaring populations.
3. To reduce the risk of future illness in seafarers: the reasons for ceasing to work prematurely can be important in determining priorities for prevention of both general and work-related diseases, as can disability or early death during retirement. Mortality information on seafarers and the findings from medical fitness examinations, social security sources, or pension funds can all contribute.
4. To develop regulations and recommendations to prevent disease and injuries: most interventions have been underpinned by regulations or guidance. Sufficient evidence may be relatively easily obtained for injuries and specific acute diseases such as scurvy. Similar evidence on long-term disease is costly to collect and analyse. In a wartime command economy information showing how the fitness of crews could be maintained, for instance by preventing malaria or venereal disease risks, was funded and the findings rapidly implemented without the need for complex political processes to be followed. In other situations sceptical interest groups must be convinced.
5. To evaluate the effectiveness of previous initiatives: continuing collection of the sort of information that has been the basis for intervention will enable results to be monitored. For instance that on scurvy, TB, malaria, and venereal disease all confirmed the success of the interventions that were made.

comparisons could be made with national statistics and other occupational groups. Docks in major port cities, where ships stayed for days or weeks, also meant that there were special medical facilities for seafarers, where there was an interest in their health problems and the scope for some limited follow up.

The scene is very different now, often with a geographical and cultural separation between ownership, the flag of the vessel, ship management, and crewing. Crewing has always been casual, especially for ratings, but as they are no longer drawn from a single national pool of seafarers, they become invisible between contracts and may move between ships of different flags. This means that follow up to assess medium- and long-term risks is more difficult, while at the same time there is less incentive for national organisations to be interested in investigating the health of seafarers as they have become effectively a global resource. At the same time the interest of ship operators and insurers in the fitness of a seafarer for their next contract of employment has increased because they are responsible for bearing the costs of any illness or injury arising during that time. This has lead to the investigation of patterns of illness at sea and to more detailed pre-embarkation medical assessments. To date little of this information has become available for study, other than to those who have paid for it. For them its use is a narrowly economic one.

Ports are increasingly located in isolated areas, with very short docking times for ships, and the number of seafarers per ship has reduced. Special health facilities for seafarers are now rare and so their value as a source of information is declining. The short turn-around times mean that, unless an illness or injury only needs out-patient treatment, the ship will not wait for the seafarer, who will then have to be flown on to catch up with it or be repatriated. As a result port hospital studies are very infrequent and only a few port clinics study their seafarer populations systematically and produce summaries of their findings.

By contrast, telemedical support for ships has developed greatly. However, these services are usually unable to follow up the advice they give and so, while they can look at the relative frequency of symptoms reported and at the advice they give on treatment, they are not able to provide outcome data to look at the effectiveness of their advice. Indeed, despite the improvements in maritime communications and the potential for simpler record keeping, there have been few studies on the outcomes of illness and injury among seafarers at sea.

Globalisation, rather than expanding the limited amount of national investigation of health risks in seafarers, has resulted in a smaller number of proprietary studies done to answer relatively short-term economic problems. At the same time the feasibility of undertaking meaningful na-

tional studies and applying their results to improve risk management for the national population of seafarers has reduced. That said, there is a well-defined knowledge base about the health of seafarers, although much of it does not meet the highest standards of epidemiological investigation. The next two articles will review this knowledge, one as it applies to illness and injury at sea, and the other will consider the evidence that links health problems and impairment to safety risks at sea. Both will provide an overview of what is known and where gaps in knowledge exist. The feasibility of filling these gaps using information from the maritime industry as it now is will be noted and the implications of this for the various maritime interest groups will be discussed, noting in particular how this can be expected to influence their attitudes to investigation and to interventions based on it.