

# Sudden cardiac event on a sea-going ship and recognition of a work-related accident

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## ABSTRACT

**Objectives.** Evaluation of the effect of selected work environment factors on a sea-going ship on the occurrence of a sudden cardiac event and its recognition as a work-related accident.

**Background.** Sudden cardiac events, myocardial infarction in particular, among crews of sea-going ships are the most frequent reasons for fatal morbid events. In more than 20% of such cases, conditions and organization of work at sea are found to be of essential importance. Problems with certification are related with the assessment of the significance and impact of specific work environment factors overlapping with classic genetic and environmental factors of diseases of atherosclerotic origin.

**Material and methods.** The analysis embraced medical documentation on the state of health and working conditions at sea concerning 30 crewmembers of Polish sea-going vessels, who had suffered from sudden cardiac events in the years 1998–2009. The impact of selected work environment factors on the legitimacy of legal recognition of the event as a work-related accident was analysed by Fisher's test and multi-factorial regression.

**Results.** The presence of classic genetic and environmental risk factors of cardiovascular events was confirmed in all persons examined. A significant effect on destabilization of the disease, deterioration of health, and the occurrence of a sudden circulation event was shown to be strictly related with isometric and dynamic effort, particularly with heat discomfort in the maritime work environment. This satisfied the legal criteria for recognition of a work-related accident in half of the cases examined.

**Conclusions.** Isometric and dynamic effort associated with work under heat stress conditions may be regarded as a decisive causative factor for a sudden cardiac event and the recognition of a work-related accident at sea.

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**Key words:** sudden cardiac event, work-related accident, physical effort at seafarers' workplace

## INTRODUCTION

The aim of research was the evaluation of whether the effect of selected maritime work environment factors satisfies criteria for the recognition of a sudden cardiac event as a work-related accident.

A number of papers indicate premature and high incidence and mortality related with circulatory events

among seafarers during work at sea [1–4]. One of the predominant causes of lethal events or evacuation from the ship is sudden cardiac event, mainly myocardial infarction, and more frequently at sea than in port [2]. In about 20% of cases, the impact of organization and conditions of work at sea was regarded as significant, thus implying medical, legal,

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and economic consequences [5, 6]. Problems with certification are related with differentiation between the impact of classic and work-related factors on the recognition of work-related accidents.

Casualty certification in Poland is based on the Act of 30 October 2002 (Law Gazette No. 199, item 1673), according to which a work-related accident is a sudden event caused by external circumstances and not only by individual features of the worker, leading to either work-related injury or death. The sudden character indicates a direct effect of the causative factor on the state of health. The external causes embrace working conditions such as physical effort, fatigue, stress, microclimate, and other unfavourable work environment factors, or admittance of persons unfit for work at a given post [7, 8]. Such situations are almost always affected by individual health features or the morbid condition of the worker, resulting from genetic factors or lifestyle, determined as internal causes. This necessitates the assessment by an expert of whether the action of the external cause was sufficient and/or predominant for the occurrence of negative work-related health consequences. All accidents on the ship, including fatal accidents, undergo assessment by the casualty commission appointed by the ship's captain. Next, all of the documentation is analysed and the verdict is issued by the Maritime Chamber of the District Court to elucidate the reasons, legal and indemnity responsibility, and to formulate preventive recommendations according to the Maritime Labour Convention, ILO, Geneva 2006 [9].

## MATERIAL AND METHODS

The analysis embraced 30 cases of sudden cardiac events that occurred in men employed on ships under the Polish flag in the years 1998–2009. The ages ranged from 28 to 61 years, average 50.2 years; period of employment 22.1 years; and an average of 22 years until the occurrence of the event. All had valid health certificates according to STCW 78/95 [10] and the majority of them worked 4-hour shifts, not exceeding weekly or monthly overtime limits, with preservation of undisturbed 11-hour daily rest.

Medical documentation before and after the event was analysed, including autopsy results, post-accident report with determination of work-related risk factors, witness testimonies, and the verdict of the court. The diagnosis of the disease or causes of death were formulated according to ICD-10.

The risk factors were assessed according to the following two groups:

- a) genetic and environmental factors (including lifestyle): carbohydrate metabolic disturbances (type 2 diabetes, glucose intolerance, incorrect glycaemia on fasting, over 110 mg/dl), lipid disorders, obesity and overweight (BMI > 25) according to criteria of the Polish Diabetes Association [11], arterial hypertension (> 140/90), ischaemic heart disease diagnosed before the event according to criteria of the European Society of Cardiology [12], positive family history of cardiovascular death, everyday physical activity (less than 3 hours per week), and active smoking;
- b) factors related to working conditions, immediately preceding the event, involved the share of:
  - isometric – static physical effort (lifting, holding, and pushing heavy objects, work in constrained position or with hands raised above shoulder level, etc.),
  - isotonic – dynamic effort (walking, going up, running, movements of limbs, etc.); these elements were evaluated according to Christensen's scale [13], since quantitative assessment of energy expenditure prior to the event was not possible [13, 14],
  - work-related stress: psychical discomfort in the worker – work environment relation according to Karasek's model [15], with particular regard to high demands and low control by the worker; sudden stress was also attributed to direct emergency situations or intensive conflicts in the work environment,
  - heat discomfort, perceived as physical overload by work at ambient temperatures exceeding 25°C, when the heat balance of the organism may be disturbed, with dehydration and dyselectrolytaemia [13].

The causative share of the above factors in the recognition of a work-related accident was analysed by Fisher's test and multi-factorial regression, assuming  $P > 0.05$  as the significance level.

The data are summarized in Tables 1–5.

**Table 1.** Sudden cardiac events in 30 crewmembers of Polish sea-going ships

Diagnosis	ICD10	Numbers of cases
Myocardial infarction	I 21	22
Acute ischaemic heart diseases	I 20	3
Sudden cardiac deaths	I 46	3
Myocarditis	I 40	1
Acute heart failure	I 50	1

**Table 2.** Genetic and environmental/lifestyle circulatory risk factors in 30 crewmembers of Polish sea-going ships

Risk factors	Numbers of cases	Cases recognized as accident at work	Case not recognized as accident at work	P 0.05
Carbohydrate metabolic disturbances	12	33%	67%	0.06
Arterial hypertension	15	53%	47%	1.000
Obesity and overweight	21	48%	52%	0.229
Lipid disorders	10	50%	50%	0.307
IHD diagnosed before the event	5	40%	60%	0.628
Smoking	23	57%	43%	1.000
Positive family history of cardiovascular death	3	70%	30%	1.000

**Table 3.** The impact of selected work environment factors on the occurrence of a sudden cardiac event in 30 crewmembers of Polish sea-going ships

Risk factors	Numbers of cases	Cases recognized as accident at work	Case not recognized as accident at work	P 0.05
Isotonic-dynamic effort	21	81%	19%	0.0001
Isometric-static physical effort	16	88%	12%	0.0001
Stress	8	34%	66%	0.242
Heat discomfort – high temperature	9	78%	22%	0.338
High humidity	8	75%	25%	0.410

**Table 4.** Genetic and environmental/lifestyle cardiac risk factors and the recognition of sudden cardiac events as work-related accidents

Risk factors	Odds ratio (OR)	P	Confidence interval (95% CI)
Carbohydrate metabolic disturbances	0.19	0.041	0.039–0.94
Arterial hypertension	0.76	0.713	0.18–3.24
Obesity and overweight	0.26	0.140	0.04–1.56
Lipid disorders	0.20	0.203	0.02–2.39
IHD diagnosed before the event	0.20	0.203	0.17–2.39
Smoking	0.97	0.913	0.18–5.39
Positive family history of cardiovascular death	0.86	0.913	0.05–13.48

**Table 5.** The impact of selected work environment factors on the recognition of a sudden cardiac event as a work-related accident in 30 crewmembers of Polish sea-going ships

Risk factors	Odds ratio (OR)	P	Confidence interval (95% CI)
Isotonic-dynamic physical effort	21.1	0.001	2.81–169.59
Isometric-static physical effort	25.6	0.001	3.63–181.43
Stress	0.34	0.210	0.064–1.82
Heat discomfort – high temperature	3.95	0.144	0.61–24.73
High humidity	1.69	0.583	0.26–11.06

## RESULTS

According to the international classification of the causes of diseases, injuries, and death (ICD-10), the diagnosed sudden cardiac events are listed in Table 1.

The final diagnosis most frequently identified acute myocardial infarction or acute ischaemic heart disease with no infarction, more rarely a sudden cardiac death related to other aetiology. In 20 of 30 cases, the event ended in a sudden death, with diagnosis confirmed upon autopsy (Table 2).

In all cases analysed, from one to several genetic and environmental/lifestyle circulatory risk factors coexisted, underlying the sudden circulatory event in the meaning of the internal factor. In Fisher's test, at the significance level assumed, their impact on the recognition and certification of a work-related accident was rejected.

The incidence of work-related factors and their impact on the recognition of a sudden cardiac event as a work-related accident are presented in Table 3.

It was found that the work-related burden with isometric-static and isotonic-dynamic effort was of essential importance in the recognition of a sudden cardiac event as a work-related accident. No statistical significance was obtained for other work environment factors.

The impact of the coexistence of genetic and environmental cardiac risk factors upon the rejection of the claim for a work-related accident was examined by multi-factorial regression. The results are summarized in Table 4.

In the evaluation of the chance quotient and statistical significance none of the coexisting genetic and environmental/lifestyle cardiac risk factors excluded the recognition of the event as a work-related accident according to legal criteria binding.

The impact of work environment factors was analysed in a similar way by multi-factorial regression. The results are given in Table 5.

A statistically significant impact of static-isometric effort on the recognition of a work-related accident has been confirmed.

## DISCUSSION

Criteria of the certification and recognition of a sudden cardiac event as a work-related accident is of essential importance in view of the high incidence of such events, their legal and indemnity consequences, as well as for potential prevention at the workplace.

As reported by many authors [6, 16–18], circulatory work-related risk factors, independent of classic

genetic and lifestyle-related factors, cause a sudden destabilization of the circulatory system, and increased morbidity and mortality in different occupational groups. Approximately 1000 sudden cardiac events per year are recognized as work-related accidents in Poland [19].

In the population of seafarers, the incidence of sudden cardiac events at sea is one of the main reasons for medical consultations abroad, disembarkation, repatriation, or death at the workplace [1–3, 20, 21]. Such events, preceded by drowning, injuries, and missing, are the main cause of death at sea. About 20% of them are recognized as work-related accidents [1].

Certification in such cases is far from precise and uniform in view of incomplete, superficial, and generalized evidence in the ship's documentation on the circumstances and causative factors of the event. This implies a necessity to expand the protocol of establishing the circumstances and causes of work-related accidents.

In the present paper, an attempt was undertaken to analyse the incidence and impact of selected work environment factors on the occurrence of sudden cardiac events in persons with coexisting classic circulatory system risk factors: both genetic and lifestyle-dependent. Their measurability, i.e. of physical effort, stress, and workplace microclimate, leaves many questions unanswered and can be determined only in approximation, based on general standards of physiology and occupational hygiene. The authors are aware that the classification of the type of effort and its duration, or intensification of stress, preceding the sudden destabilization of circulation at sea is only approximate, based on Christensen's scale (physical overload) or Karasek's model of stress [13, 15].

Nonetheless, the results of the analysis by both statistical methods employed indicate a key role of static physical effort, the most frequent and strong causative factor of a sudden cardiac event, in the recognition of a work-related accident. Tofler et al. and Makowiec-Dąbrowska [14, 22] point out that its presence, preceding by 1 hour the occurrence of myocardial infarction symptoms, is noted in at least 18% of persons with ischaemic heart disease. According to the results of Fisher's test, such a factor may be responsible for circulatory decompensation. The authors cited above indicate its presence before the occurrence of the sudden cardiac event in about 30% of persons. In 52% it is preceded by a mixed-type effort (*idem*). Such an effect is observed

particularly in persons who, as in the majority of cases examined, have a sedentary type of work and have no regular dosed physical exercise and/or work under uncomfortable heat conditions [23, 24]. Both factors combined contributed to the recognition of work-related accidents in 15 persons (50%).

In the material analysed, the incidence and intensity of stress were not found to aggravate the course of atherosclerotic disease and hence were not regarded as a coexisting cause of work-related accident, as suggested by [15, 16, 18, 25]. In our quantitatively modest material of 30 cases, events having a character of acute stress were too rare to be "noticed" by and to influence the statistical analysis.

In 20 of 30 cases examined, the cardiac event ended with death either on the ship or shortly after disembarkation. Such a number of fatal events at sea, compared to 6-12% mortality on the land, may be accounted for by the specificity of work and life on the ship [1, 2], i.e. the lack of qualified medical assistance, diagnostic problems, limited medicine resources, and the lapse of time: always above 1-2 hours, a condition crucial to restore proper circulation and to limit myocardial necrosis after aggressive pharmacological and invasive treatment while in hospital conditions.

## CONCLUSIONS

1. Static and dynamic physical effort, preceding the event by 1-4 hours, frequently associated with work under unfavourable heat conditions, is the most important in certification and recognition of a sudden cardiac event on a sea-going ship.
2. The coexistence of genetic and environmental circulatory risk factors is a natural issue underlying the event and does not exclude recognition of a work-related accident.
3. For more accurate analysis of criteria for recognition of a sudden cardiac event as a work-related accident, an extension of casualty reports to include a precise standardized description of the character and conditions of work is recommended.

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