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## Mountain Rescue in Non-Profit Organizations: Interdisciplinary Research Spectrum in Mountain Tourism

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**Abstract:**

**Purpose:** The purpose of the presented article is to fill the existing epistemological gap in the analyzed phenomenon, which will be filled with aspects of mountain rescue in non-profit organizations. In connection with the above, certain issues may meet with the interest of the world of science, which will expand the research horizons and theoretical perspectives of the analyzed social processes. In addition, the article may become a contribution to the increase in the publishing activity and development of a bibliographic base, that is a literary source of scientific knowledge in the field of activities of non-profit mountain rescue organizations. This article is the first study that is a synthesis of scientific achievements in the field of professional mountain rescue. It is a compilation of the most important research results published so far in the field of saving people in the mountains.

**Design/Methodology/Approach:** The research used a theoretical analysis focused on the presentation of source literature and a literature review showing the directions, areas and research issues in the studied thematic area, mountain rescue.

**Findings:** Mountain rescue is an interdisciplinary phenomenon and process that includes knowledge and skills in many fields and scientific disciplines. Among the sciences that significantly affect the practical functioning of mountain rescue, the following can be identified: medical sciences, health sciences, technical and engineering sciences as well as social sciences.

**Practical Implications:** The further development of research on the presented aspects of mountain rescue leads to the improvement of rescue strategies and techniques used in them. Knowledge of the presented research areas allows scientists to constantly deepen their research and theory in this field: technology for rescue and transport, life functions of the human body in mountain accident conditions and human behavior during mountain activity.

**Originality/value:** The activities of mountain rescue organizations include various forms of conducting rescue operations, which include the following aspects: medical and therapeutic, logistics and transport, meteorological, technological, psychosocial and, last but not least, competence and training.

**Keywords:** Mountain rescue, non-profit organizations, sciences research in mountain rescue.

**JEL classification :** H4, I1, I11, I19.

**Paper Type:** Critical review of literature.

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## 1. Introduction

This article is the first study that is a synthesis of scientific achievements in the field of professional mountain rescue. It is a compilation of the most important research results published so far in the field of saving people in the mountains. Today, security has become an extremely important stimulus for the economy, including tourism, with particular emphasis on mountain tourism. Scientific research conducted in the field of mountain rescue becomes a very important element in the development of safety in the mountains. They lead to the systematic improvement of rescue methods and techniques that are used by mountain rescue organizations.

Mountain rescue is a specific form of non-profit organization from the third sector not only because it is focused on saving human health and life in objectively dangerous mountain conditions. An extremely important factor, but almost completely imperceptible, and therefore probably overlooked, is the fact that the profits generated by it are determined by the effectiveness of its intervention activity. This, on the one hand, is conditioned by the effectiveness of organization management in raising funds for statutory activities and, on the other hand, by implementing research results in rescue practice. The last aspect is completely absent in scientific studies and invisible in the literature on the subject. In order to change this state of affairs and to fill the epistemological and practical gap in the signaled aspect, we will present a review of scientific research as determinants of the intervention activity of a non-profit mountain rescue organization.

Credibility and trust are the basis for effective fundraising for statutory activities (Koszember-Wilk, 2006). The literature on non-profit management to date uses the overhead ratio of nonprofits as a measure of performance, but it is worth getting acquainted with alternative, interesting, modern measurement methods (Coupet and Berrett, 2018). This problem is not an issue of this article, which is why we only signal it as highly useful for assessing managerial work (De los Mozos, Duarte, and Ruiz, 2016).

Mountain rescue organizations in Europe operate as non-governmental organizations whose legal personality and social activity are based on the provisions of national law (tax law, administrative law, civil law, criminal law, and so on). Most of them belong to the international association called *International Commission for Alpine Rescue (ICAR)*<sup>1</sup> as an organization with advisory, research and implementation competences in the field of mountain rescue in the world. National mountain rescue organizations have full autonomy and subsidiarity within the jurisdiction of the Member States, but can implement new scientific and technological proposals in the framework of their specific preventive and rescue activities.

Mountain Volunteer Search and Rescue<sup>2</sup> is one of the rescue organizations operating in Europe in the field of mountain rescue, whose functioning covers the area of the Sudetes and Western Carpathians in Poland. For example, in Poland the number of

social activists, GOPR volunteer rescuers, is almost 85% of the staffing, while the remaining 15% are professional rescuers ensuring the continuity of implementation of statutory goals and tasks, as well as administrative and technical service employees (Mrozowicz and Halemba 2012; Mrozowicz, 2015).

The issues of non-profit organizations that participate and specialize in mountain rescue are not properly thoroughly discussed in the scientific literature. Existing publications relate to specialist rescue issues and are published in publications in the fields of technical, social and medical sciences. They are primarily addressed to a small group of specialists and act as application materials whose task is to improve methods and techniques of saving in the mountains. Therefore, theoreticians and practitioners of the narrow current of research become beneficiaries of research results, and there are no interdisciplinary studies. The subject matter is completely absent in the literature on management sciences which, by their theoretical and methodological essence, are based on detailed sciences and follow eclectic and compilation studies.

The theoretical goal of the analysis was to present an interdisciplinary thematic spectrum of modern scientific research in the field of saving human health and life in high mountain areas, as determinants of potential financial and social profits that are achieved by non-profit mountain rescue organizations. The universality of research in this field allows researchers to draw global implications that allow for universal generalizations.

The research goal of our analysis was to pre-determine the theoretical perspective and research framework in which you analyze specific problems and issues arising from the activity of people in mountain areas (skiing, trekking, mountaineering and its qualified forms), as well as mountain rescuers, who help them in situations of threats, accidents and disasters in terrestrial (also underground), avalanche and air conditions. In order to achieve research objectives, we asked the following three questions:

1. *What are the general basics of mountain rescue organizations in the world?*
2. *In what types of activities is the mountain rescue process manifested?*
3. *What kind of scientific research is carried out in non-profit mountain rescue organizations?*

## **2. Theoretical Aspects of the Functioning of Non-Profit Organizations**

The issues of non-profit organizations are very well documented, they do not cause polemics, polarizations of views are not violent, paradigms possess a significant degree of theoretical petrification, creating in the management sciences a coherent stream of theory and research of third sector organizations (Anheier 2005; Drucker 2006; Hartigan, 2006)<sup>6</sup>. From the enormity of scientific achievements, devoted to the above-mentioned topics, we have selected for example those which are related to the

problems we undertake and which contain the most current challenges. Drucker addresses the issues of mission, performance, human resources and relationships, leadership and management that have practical significance for the management of non-profit organizations (Drucker, 2011). Young (2012) showed the prospects for the development of educational programs in the field of non-profit management at universities in the USA. In another study, he used the case study method in which he emphasized entrepreneurship of specific aspects of social activity management (Young, 2012). V. Potocan, M. Hagan and Z. Nedelko presented the results of research on managerial solutions in non-profit organizations, showing a solid theoretical framework and the latest results of empirical research on the effective management of such organizations (Potocan, Hagan, and Nedelko, 2016). R. Busch presented determinants of effectiveness and efficiency of management in the non-profit sector including effective leadership (Bush, 2003), while S.L. Allen, J.E. Smith and N. Da Silva focus their analysis on leadership effectiveness and efficiency in managing changes in non-profit organizations (Allen, Smith, and Da Silva, 2013).

M.A. Hagar focused his scientific analysis on the cyclical life of a non-profit organization which, like any system, undergoes a "flow effect". Organizational life cycle refers to different stages of activity, from the phase of ideas and concepts to the downfall and disintegration. The "cycle" means that failing organizations can be restored to the growth phase, while most theories merely admit that organizations at different stages of life have different needs and potential (Hagar, 2017). The transformation is incorporated into the system and the system is constantly evolving. B. Geer developed an analysis of transformational leadership and engagement issues, which show that higher levels of non-profit responsibility are associated with higher levels of organizational involvement in operational standards and higher levels of transformational leadership, primarily in the activities of organization leaders (Geer, 2008).

The concept of social capital of the organization is very coherent, useful and important for non-profit organizations. As N.K. King observes, *"Non-profit organizations must maintain and strengthen the original social capital in which they were created and extend it to a number of key areas. Non-profit organizations and their leaders must support social capital to recruit and develop board members, executive staff and specialists, to obtain philanthropic support, develop strategic partnerships, engage in social missions, improve relations with the local community and create a common strategic vision and mission in the organization and its members"* (King, 2004).

The theoretical perspective, terminology framework and practical dimension of non-profit organizations have a uniform and coherent scientific paradigm, according to which non-profit organizations obtain the necessary financial resources from various public budgets: state, regional or local. They can be run as an economic activity, but their revenues are allocated to finance their activity and cannot be distributed among their members. All financial resources are allocated to the implementation of the

statutory objectives of the organization, and the profit generated is not an objective, but determines the increase in its functional efficiency (Grzelońska, 2011). We want to emphasize that although such organizations are not focused on generating financial profit, they have to bring enough income to achieve the social goals specified in the statute. Non-profit organizations obtain finance to run their statutory activities from a variety of sources, for example, through income from donations from individual donors or foundations, corporate sponsorship, government funding, programs, services or the sale of goods and investments (De los Mozos, Duarte, and Ruiz, 2016). The activities of non-profit mountain rescue organizations have three goals:

- 1) *survival and development* – achieved through effective management of organizations operating as entities of the so-called third sector of the economy (for example, in the area of PR, social communication, or marketing narrative in obtaining funds for statutory activity);
- 2) *prevention and promotion of safety in the mountains and, above all, providing direct assistance to the victims of mountain accidents* – achieved through effective strategic and operational activity in the field of managing the owned social capital, which is largely based on the social work of their members (for example, management of training activities, implementation of modern rescue technologies, conducting preventive activities, as a priority by coordinating operational processes in conducting direct rescue operations);
- 3) *inspiring, supporting and popularizing scientific activities*.

### **3. Activities of the International Commission for Alpine Rescue Association**

The International Commission for Alpine Rescue (ICAR) is registered as an association under Swiss law and its seat is Kloten in Switzerland (ICAR Statute, 2019, paragraph 1, p. 1). ICAR obtained the status of a non-profit organization under tax law legalized by the institutions of the Canton of Zurich in Switzerland on April 10, 2007 ([www.alpine-rescue.org](http://www.alpine-rescue.org)). ICAR brings together mountain rescue organizations that operate independently on different continents of the world, in diverse organizational, geographical, political, social, cultural and economic conditions.

ICAR and its affiliates belong to the type of non-profit organizations whose common denominator is a voluntary, permanent and self-governing association for non-profit purposes. They independently defined their goals, action programs and organizational structures and adopted internal acts regarding their activity based on the social work of their members (Mrozowicz, 2013). Currently ICAR brings together 118 international organizations that participate in various rescue fields, including 30 in the field of mountain rescue, which operate independently in 40 countries around the world ([www.alpine-rescue.org](http://www.alpine-rescue.org)). The main statutory goals of ICAR are: international cooperation concerning the problems of mountain rescue,

providing the most effective methods of rescuing injured mountaineers, tourists and skiers, as well as providing assistance in improving rescue techniques, obtaining information on the progress of scientific research as well as prevention and accident prevention in mountain and high mountain areas (ICAR Statute, 2019, paragraph 2, p. 1). The discussed organization realizes its goals based on a system distinguished from the aspects of practical rescue operations and the resulting preventive activity, which includes the following subsystems: terrestrial, avalanche, air and medical rescue. They operate on the basis of the structure of four specialized committees.

Analysis of the literature on the subject, review of specialist literature, as well as verification of experimental methods, expert interview and participant observation (which we use in our research) justify the conclusion that mountain rescue, due to its geophysical, meteorological and traumatological specificity, is a type of activity of multifaceted and multidimensional characteristics (Mrozowicz and Halemba, 2012).

The operational and strategic activity of non-profit mountain rescue organizations associated in ICAR are implemented at the level of national associations, operating independently and separately in individual Member States, includes the following types of preventive and above all intervention activities (Mrozowicz and Halemba 2012; Mrozowicz, 2013; Mrozowicz, 2015; [www.alpine-rescue.org](http://www.alpine-rescue.org)):

- a) mountain rescue in a geomorphological environment aimed at reducing the causes and eliminating the effects of accidents whose coordination and logistics activities are carried out in ground conditions (without the need for air transport);
- b) mountain rescue mainly focused on exploration activities in winter as a result of avalanche disasters (with the need to use specialized navigation, transport and medical technologies);
- c) mountain rescue determined by the need to use technology and the air fleet (carried out as a basic or indispensable measure in achieving the objectives of the action);
- d) mountain rescue focused on the implementation of specialized medical methodology (with the need to use methods, resources and therapeutic techniques with a high degree of medical professionalism).

Due to the multifaceted and multidimensional characteristics of mountain rescue, the ICAR organization, whose statutory objectives focus on the evolution and improvement of rescue practice, has identified four substructures in its organizational structure. Each of them has a slightly different domain of operation, specialization and functions, whose divergent (autonomous and isolated) functioning is based on the specialization of learning and system operation, while converged (heteronomous and combined) operation is based on the principle of diversification (versatility). As a result, between both forms there are bi-directional interactions and feedback, whose end result is based on the principle of system synergy. The results of research work used in practical mountain rescue activities are a real example of this.

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The highest authority at ICAR is exercised by the general congress of delegates from national organizations, which recently took place in Zakopane, Poland (19 October 2019). Executive power is held by the board headed by the president, while the coordination of organizational processes at ICAR is based on the activities of substructures, the ICAR Commissions, specializing in independent domains:

- a) The ICAR Terrestrial Rescue Commission – deals with issues of rescue operations in ski and high mountain conditions, which are the basic and standard type of mountain rescue;
- b) The ICAR Avalanche Rescue Commission – participant in the subject of conditions for rescue operations in avalanche conditions and their determinants: snow physics, avalanche meteorology, avalanche architecture, and so on;
- c) ) The ICAR Air Rescue Commission – exploring the issues of rescue operations whose goals are implemented in relation to the needs of terrestrial and avalanche rescue;
- d) ) The ICAR Alpine Emergency Medicine Commission – addressing issues strictly related to saving and restoring life functions of a person as a result of an accident in the mountains and in the mountain environment, mainly in pre-hospital form.

The abstracted fields of practical mountain rescue are reflected in the repertoire of scientific research, which is carried out in relation to the objectives and tasks of individual commissions and the entire ICAR organization. The implementation and application value of conducted research is expressed by a surprisingly large amount of scientific work that is devoted to key issues of saving human life and health in high mountain areas.

In the light of the authors' retrospective analysis of literature on the subject of mountain rescue in the years 2000-2020, that is in the approximate period of existence of one generation, 197 scientific publications have been published around the topic of mountain rescue. We based the preliminary literary research on the indexed databases of scientific journals (Scopus, Web of Science) using semantic selection. We filtered the research issues raised in the magazines by applying a semantic criterion in the form of the expression "mountain rescue". The issues of publications devoted to mountain rescue turned out to be multidisciplinary and interdisciplinary, containing mainly highly specialized research studies. Due to our research goals, we decided to cite also those which do not have common theoretical and research areas with the leading issues of organization and management sciences. However, they cannot be overlooked because they constitute the scientific basis for the operation of non-profit mountain rescue organizations.

#### **4. Research Areas of Mountain Rescue in the World**

A review of the mountain rescue literature indicates unequivocally that it takes up highly specialized and typically rescue problems, not focusing completely on scientific and practical issues in the field of management of non-profit organizations.

It is therefore possible to review the mountain rescue issues only in the sense of its conditions and specialized tasks. National and local publications, if any, are completely unavailable in the digitized version or published with a circulation which significantly limits or simply prevents their availability.

Research in the field of interdisciplinary mountain rescue is based on several categories of threats and dangers. The functioning of these types of organizations in the world is directed at prevention and minimization of those threats and dangers. The differences and analogies are caused by some characteristic conditions that cause people on different continents and in different parts of the world to strive to counteract accidents and disasters in the mountains. Different countries, based on legal regulations, often conduct a different preventive and rescue policy in the field of mountain rescue, which results from the huge number of variables that differentiate strategic and operational activities in the area of science and practice.

In other words, problems related to the occurrence of hazards and mountain accidents, as well as countermeasures that would prevent them, are a source of research questions as well as inspiration and justification for conducting appropriate research in the future. Regardless of geographical location, specific features of the mountain environment, political, socio-economic, climatic and geophysical conditions, in a global perspective we can talk about the existence of a universal phenomenon which combines culture and economy. Mountain rescue has a rich and lofty history, a noble ethos woven with the biographies of famous figures and nameless heroes who have been intertwined for centuries with the passion of helping people in the mountains. As Graeme Walker writes in a suggestive way: *„Mountain rescuers are humble people who acknowledge human vulnerability. They have great respect for the power of nature and often witness its final dominance over the fragility of life. They understand the risk, think calmly under pressure, and have a structured approach to problem solving. Interdependence and teamwork are the basis for successful search or rescue. In summary, the personal qualities required for mountain rescue do not differ much from those that are important in general practice”* (Walker, 2005).

Due to the discursive nature of the study, we did not include in our preliminary literature review any cultural studies publications that would show the sociological and psychological depth of the presented phenomenon. From the point of view of organization and management sciences, an attempt at the synthesis and synergy of theoretically and terminally isolated areas of science and practice, research and pragmatic activity, hermetic language of high technology and professional work jargon is gaining importance. This publication is only an attempt to coherence those aspects of mountain rescue that in total create the described socio-cultural and economic phenomenon, and showing it in the light of the conducted scientific research, inspired by the needs of specialist practice.

The above conclusion leads to another detailed goal of the undertaken analysis,



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namely an attempt to present the problems of mountain rescue in the perspective of challenges and problems that concern it. The basis of the aforementioned analysis will be the results of scientific research on various scientific fields and disciplines, which are also the basis for the development of mountain rescue in practical terms. Due to the fact that we have conducted a review of the subject literature in this regard based on indexed world resource databases, its implications can be generalized. It will become the basis for conclusions about the tasks and problems in the light of which modern mountain rescue in the world is developing as a specific form of non-profit organization. It should be indicated here that it is a multifaceted activity, based on functional multilateralism, which means applying knowledge and skills from various areas of science and practice to rescue operations. Therefore, the practical goal of our research was to present mountain rescue and its scientific basis in an interdisciplinary form. The review of the literature is organized according to aspects that reflect the research and scientific publications devoted to the issues of mountain rescue, among which there are the following aspects: medical-therapeutic, logistics-transport, meteorological, technological, psychosocial and competence-training.

Scientific research applied to the mountain rescue practice through the coordination activities of the ICAR commission can be divided into the above-mentioned thematic groups. For cognitive-perceptual and editorial reasons and in order to make the analysis clear, concise and applicable in empirical research, we have divided scientific publications in terms of issues that correspond to the specific work of the ICAR Commission.

#### **4.1 Scientific Research in the Area of Terrestrial Rescue**

The growing popularity of sporting activities in the mountains, such as hiking, climbing, skiing and snowboarding has meant that the number of people visiting the mountain environment is constantly and systematically growing. Because mountain areas impose relatively high physical demands on tourists, the risk of accidents, and sometimes also death, is inevitable. J.S. Windsor, P.G. Firth, M.P. Grocott and their associates noticed that mortality for some types of mountain activities is comparable to hang gliding, parachuting and boxing, which are traditionally considered dangerous. The results of their research show that deaths in the mountains are most often caused by mechanical trauma, high-altitude disease, body cooling, avalanche filling and sudden heart attack (Windsor, Firth, Grocott, Rodway, and Montgomery, 2009).

The popularity of mining tourism around the world has led to an increase in the number of people exposed to the cold and extreme conditions that accompany recreation, as well as qualified forms of tourism in the mountains that potentially have cold restrictions. E. Procter, H. Brugger and M. Burtcher claim, on the basis of their research, that hypothermia cases are reported during climbing, trekking, hiking, skiing and snowboarding. Hypothermia occurs most frequently when climbing at

high altitudes (Procter, Brugger, and Burtcher, 2018).

In the context of effective coordination and management of rescue operations in the mountains, the knowledge of methods and techniques of pre-medical first aid as well as medical self-help for participants of alpine expeditions is gaining importance. Th. Küpper, D. Wermelskirchen, Th. Beeker and R. Waanders in their studies evaluated the knowledge of first aid for mountaineers who explore routes of considerable difficulty in the Western Alps. The results of their research showed that knowledge proved to be relatively poor. The best results were obtained for sudden heart disease, altitude sickness and hypovolemic shock, and the worst for hypothermia, accident injuries and pain management. We want to emphasize that traumatic injuries account for as much as about 50% of mountain accidents, which further aggravates the essence of the problem (Küpper, Wermelskirchen, Beeker, and Waanders, 2003).

W.E. Brandenburg and B.W. Locke, based on the epidemiology of injuries and illnesses during mountain expeditions (trekking, backpacking, climbing) in Colorado in the USA, found that the most common consequences of accidents were: musculoskeletal injuries, fractures, sprains and skin wounds. The authors noted that mountaineer medical kits varied widely and often lacked necessary items. According to the researchers, the basic medical kit used in the mountains should include elements for isolating substances in the body, materials for immobilization, painkillers, wound care products as well as drugs for gastrointestinal complaints and flu-like diseases. This suggests the need for improved guidelines. Brandenburg and Locke suggest that a similar methodology should be applied in relation to other mountain regions where there is limited formal healthcare (Brandenburg and Locke, 2017). The results of the research by B. Soulé, B. Lefèvre and E. Boutroy showed that mountain accidents mainly involve three types of activity: hiking, climbing and skiing (regardless of whether they resulted in death or injury) (Soulé, Lefèvre, and Boutroy, 2017).

Retrospective studies of A. Chamarro and J. Fernández-Castro of survivors of accidents that occurred during climbing, downhill skiing and mountaineering, hiking, cycling and mountain racing, showed their real genesis. The diagnosed causes of accidents are: geomorphological factors, defective equipment, medical events, technical errors and time pressure, as well as their compilations. The results of their research showed that in the case of downhill skiing the direct causes of accidents were mainly: excessive speed, technical errors on skis and fatigue. For mountain climbers, errors in decision making and skiing technique have become the direct causes. The determinants of accidents in climbing were adverse weather conditions, terrain difficulty, fatigue, insufficient physical preparation and insufficient skills (Chamarro and Fernández-Castro, 2009).

M. Niedermeier, H. Gatterer, E. Pocecco and co-authors stated on the basis of comprehensive preliminary literature research that the main causes of death during alpine (downhill) skiing, snowboard, cross-country skiing, ski tourism and sledging

were traumatic incidents (fall with fracture) and non-traumatic incidents (heart stroke) as well as avalanche suffocation. In their opinion, preventive measures should include improving sports skills and fitness, the use of protective equipment, information technologies, well-targeted and intensive training programs on avalanche threats and, last but not least, sports and medical counseling (Niedermeier, Gatterer, Pocecco, Frühauf, Faulhaber, Menz, Burtcher, Posch, Ruedl, and Burtcher, 2019).

I.S. Alsukayti and Ch. Edwards believe that the implementation of the communication system based on the IP protocol in the field of mountain rescue would enable a successful conduct of search and rescue missions. The mentioned authors proposed an innovative IT solution called Multihomed Mobile Network Architecture (MMNA), that is a comprehensive solution for multi-homed mobility. Multi-addressing is an IT solution that involves the use of more than one card connected to the IP network in a computer or server node, which allows to increase and balance the server's bandwidth (Fall and Stevens, 2013). The MMNA was experimentally implemented and evaluated in the configuration of the test stand in order to examine its effectiveness and feasibility, taking into account an example of a rescue scenario. The cited scientists emphasize the practicality of the benefits of implementing MMNA in the real world in reducing the consequences of accidents and compression of secondary injuries, by increasing the efficiency of locating them and increasing the speed of rescuers reaching the scene (Alsukayti and Edwards, 2016).

#### **4.2 Scientific Research in the Field of Avalanche Rescue**

The basis of avalanche rescue, in addition to obvious technological conditions, is the ability to organize emergency and immediate self-help and coordinate the work of small and adhoc search and rescue teams. An important issue in this type of avalanche accidents is to maximally reduce the time spent under piles of snow of the person who is primarily at risk of suffocation due to lack of air. N.A. Silverton, S.E. McIntosh and H.S. Kim carried out rescue-relevant research in the Wasatch and Uinta Mountains in Utah, USA. The purpose of that research was to assess avalanche safety practices and to identify groups that should become the target of avalanche safety education. The researchers assumed that the criterion for the minimum safe activity in the mountains was: 1) traveling with a partner, 2) wearing an avalanche transceiver and 3) carrying a shovel. The study participants were downhill skiers, snowboarders, users of rockets and snowmobiles from the state of Utah, as well as visitors. Skiers from the province showed the highest level of preparation for an avalanche, with 98% carrying avalanche transceivers, 98% carrying shovels, 77% carrying probes, and 86% having passed the avalanche safety course. Downhill skiers and snowboarders from the Utah province proved to be better prepared than scooter and snowshoe users from outside the state (Silverton, McIntosh, and Kim, 2007).

In the Alps, emergency medical services regularly participate in avalanche rescue missions. However, the manner in which the rescue helicopter best supports avalanche rescue missions raises some controversy. P. Mair, C. Frimmel, G. Vergeiner and their co-workers examined the advantages and limitations of early dispatch of rescue helicopters for avalanche accidents. Data on the characteristics of rescue missions and the severity of medical emergencies were obtained from the assessment of over 200 helicopter rescue missions in the Austrian province of Tyrol. As a result of the analysis, it was found that the survival rate of avalanche victims removed from the snow after the arrival of the helicopter was much lower than for victims found before the arrival of the helicopter. The arrival time of the helicopter was determining in this situation. In 56% of cases, no victim was present at the site of the avalanche when the helicopter arrived (and thus was unnecessary), as the victim was already under premedical care in transport to the hospital (Mair, Frimmel, Vergeiner, Hohlrieder, Moroder, Hoesl, and Voelckel, 2013).

The number of avalanche accidents has increased significantly in recent decades due to the growing popularity of winter outdoor activities. The International Commission for Mountain Emergency Medicine (ICAR Medcom) and the Wilderness Medical Society (WMS) have recently published evidence-based recommendations on the epidemiology of avalanche accidents, presentation of the latest achievements in the field of pathophysiology of snow avalanches as well as elaboration on the latest progress in the treatment of snow avalanche victims at the scene of an accident (Strapazzon and Brugger, 2018). G. Strapazzon and H. Brugger state that, despite these recommendations, recent studies have shown poor knowledge and compatibility between both providers and victims. In the light of the conducted research, U. Pietsch, V. Lischke, C. Pietsch C. and K.H. Kopp note that mountain rescue operations often pose ambulance crews with extremely difficult and non-standard challenges. One of the most difficult problems is pre-hospital care for patients with cardiac arrest during evacuation and transport, when cardiopulmonary resuscitation of an avalanche victim should be carried out. A specialized mechanical chest compression device is then used, which minimizes the contactless time and ensures high-quality chest compressions during the evacuation of the patient from the accident site (Pietsch, Lischke, Pietsch, and Kopp, 2014).

The research of D.K. Kornhall and J. Martens-Nielsen shows that avalanche descents are very often fatal events with an overall mortality rate of 23%. Mortality increases dramatically to 50% in the event of complete snow covering. Then the time in which help is provided is crucial. Significant support can be given by entities that do not formally provide medical assistance, but due to the fact that they operate in mountainous regions, they can support the activities of regular emergency services. Armed forces are often deployed in mountainous regions to prepare for war in the mountains or as part of conflicts that are taking place within them. Therefore, it is important that doctors associated with units operating in mountain regions have knowledge about the medical management of avalanche victims (Kornhall, Martens-Nielsen, 2016).

H. Brugger, P. Paal and J. Boyd have shown that in North America and Europe, about 150 people die annually from avalanches and the number of fatalities in developing countries is many times higher (2017). Four factors determine the survival rate of avalanche victims: the extent of avalanche filling, the duration of filling, the presence of an air pocket and free airways, and the severity of the injury. According to the data obtained by these researchers from studies conducted in Switzerland, the avalanche mortality rate is 23%, but it largely depends on the degree of filling. While the mortality rate for completely buried (head under snow) victims of avalanches is 52.4%, it is only 4.2% for partially buried (without heads). In addition, the survival of completely buried victims drops to 30% in the first 35 minutes, initially due to death as a result of fatal injury, and then as a result of suffocation within 20-35 minutes. H. Brugger, P. Paal and J. Boyd write that from now on the survival is gradually decreasing, and the victims who have not suffered fatal injuries and are able to breathe under snow are slowly undergoing hypoxia, hypercapnia and hypothermia. In the absence of fatal injuries, rescue strategies depend on the time of avalanche burial and the victim's body temperature. With a burying time of less than 35 minutes, the survival depends on preventing asphyxiation by rapid snow clearing, adequate airway management and cardiopulmonary resuscitation. In the event of avalanche burial time of over 35 minutes, the fight against hypothermia is extremely important (Brugger, Paal, and Boyd, 2011).

C. Tilburg, C.K Grissom, K. Zafren and co-authors write that in order to provide physicians and rescuers with best practice guidance in rescuing avalanche victims, the Wilderness Medical Society (WMS) has developed evidence-based guidelines for the prevention, rescue and medical management of snow avalanche and avalanche victims. These recommendations are developed on the basis of the American College of Chest Physicians classification (Van Tilburg, Grissom, Zafren, McIntosh, Radwin, Paal, Haegeli, Smith, Wheeler, Weber, Tremper, and Brugger, 2017).

#### **4.3 Scientific Research in the Field of Air Rescue**

In remote and mountainous areas, helicopters of emergency medical services (Helicopter Emergency Medical Service, HEMS) are used to accelerate evacuation and provide pre-hospital advanced support for life processes in trauma conditions (Advanced Trauma Life Support, ATLS). F. Billmann, C. Burnett, S. Welke and T. Bokor-Billmann note that the coincidence of extended pre-hospital periods during rescue operations in the mountains with critical impairment of vital functions justifies the need for an early use of ATLS in HEMS mountain rescue missions (Billmann, Burnett, Welke, and Bokor-Billmann, 2013). ATLS consists of several difficult and important medical procedures. It follows from the research of J. Ausserer, E. Moritz, M. Stroehle and others that pre-hospital endotracheal intubation is possible with a high success rate and low complication rate also in the mountain rescue scenario. Pre-hospital resuscitation is limited and hypotension is reversible if

only one third of patients are admitted to hospital. Prolonged prehospital hypotension remains an unsolved problem in half of all patients with brain trauma and indicates difficulties in raising blood pressure to the desired level. Researchers indicate that despite technical limitations, ATLS is feasible for an experienced emergency physician even in most rope rescue operations (Ausserer, Moritz, Stroehle, Brugger, Strapazzon, Rauch, and Kettner, 2017).

Another problem of air rescue in the mountains is the extraction and transport of human external cargo (Human External Cargo, HEC) during helicopter rescue missions, which is now commonly used in mountain rescue services. What is more, long ropes or winches offer the opportunity to provide professional medical care at the scene of the accident (<https://www.mountain-solutions.net/resources/blog/what-hec-means-mountain-rescue>)<sup>45</sup>. Particularly difficult conditions prevail in the longwall environment with additional exposure and require not only medical competence, but also specialist rescue skills.

In the research of U. Pietsch, G. Strapazzon, D. Ambühl and their colleagues, all helicopter rescue missions carried out in the high-mountain region of Switzerland in 2010-2016 were retrospectively analyzed. It turned out that out of the 11.078 rescue missions, 1.137 (10%) required the use of HEC, 3% (n = 29) - tracheal intubation, and 2% (n = 14) cardiopulmonary resuscitation and had to be performed on site prior to HEC extraction. The most common medical intervention on site was anesthesia or analgesia, in 17% (n = 142) fentanyl or ketamine were used. Since medical interventions must be performed in difficult terrain, with limited human resources and limited surveillance, research findings indicate that doctors, who have clinical experience in these procedures and are specially and systematically trained in HEC technology, need to be present at the scene (Pietsch, Strapazzon, Ambühl, Lischke, Rauch, and Knapp, 2017).

M. Pasquier, L. Marxer, H. Duplain and co-authors conducted research based on helicopter rescue missions to mountain huts in the Swiss Alps. Of all the 14.872 rescue missions undertaken during the 10-year research period, 309 (2.1%) were carried out with the help of a helicopter from mountain huts at an average height of  $2794 \pm 459$  m. The average age of accident victims was  $43 \pm 16$ , and 66% were male. The majority (89%) of the injured was transported to hospital, and only 12 (3.9%) patients had to stay longer than 48 hours. Hospital diagnoses varied widely. Injury accounted for 50%, and altitude sickness - 7% of cases.

Helicopter rescue missions in mountain huts constitute a small part of all rescue missions (2.1%). According to the researchers, mountain huts owners must be prepared for such situations, because they will often have to act as first aiders in the event of medical problems (Pasquier, Marxer, Duplain, Frochoux, Selz, Métrailer, Zen Ruffinen, and Hugli, 2017). The technological problem in air rescue is the improvement of helicopter blades in order to reduce vibrations during air transport, to minimize the risk of secondary injuries and to reduce the likelihood of

aggravation of primary injuries in victims. E. Alberti, D. Chiappa, G. Moschioni, B. Saggin, and M. Tarabini noted that: “In mountain-rescue operations injured people are generally exposed to vibrations and shocks that can be potential causes of physical conditions worsening. (...) The results of a measurement campaign carried-out in order to outline, identify and quantify the excitations a human body is exposed to, during typical transportation phases related to mountain-rescue operations” (Alberti, Chiappa, Moschioni, Saggin, and Tarabini 2006). It turns out that in different phases of the rescue operation, the intensity of vibration of the injured body varies, with the greatest variation in vibration occurring in the early stages of the rescue operation, before bringing the injured person on board the helicopter.

S. Viswamurthy and R. Ganguli investigated the use of many active trailing edge flaps to reduce vibration in the helicopter rotor. The strong aeroelastic interaction between the unstable aerodynamic environment and the rotating blades is modeled using comprehensive aeroelastic analysis of helicopter rotors (Viswamurthy, Ganguli, 2006). These studies are still being continued by S. Kumar, D. Komp, J. Rauleder and M. Hajek (Kumar, Komp, Rauleder, and Hajek, 2019). The mechanism which has been used is the dynamically activated morphing of the flap curvature, known as Fish Bone Active Camber (FishBAC), which smoothly deforms the bend on the stern part of the flap.

#### **4.4 Scientific Research in the Area of Emergency Medical Services**

Chest compression devices are very useful during rescue operations in the mountains, but they can cause delays in transporting the injured person, unless they are directly available. The time delay is due to the need to wait for the equipment to be delivered to the scene of the accident, because the initial diagnosis of the accident does not always indicate the need for immediate transport. The cited studies aimed to compare manual and mechanical cardiopulmonary resuscitation (Cardiopulmonary Resuscitation, CPR) during transport on a sled connected to a snowmobile. Sixteen healthcare providers in the mountains of Norway participated in the study of O. Thomassen, S.C. Skai J. Assmuss, O. Østerås and their colleagues, which involved simulation of four different combined scenarios of resuscitation on a sled motionless and during transport, and two mechanical devices for chest compression during sled transport. As a result of the study, no significant difference was observed between moving and stationary conditions in relation to manual compression ratio and compression depth. It follows that manual compression of the chest is possible on a snowmobile during transport, even in difficult terrain. This experimental study shows that high-quality chest compressions and manual ventilation can be performed on a patient intubated during short-term toboggan transport (Thomassen, Skaiaa, Assmuss, Østerås, Heltne, Wik, and Brattebo, 2017).

In the light of the results of literature studies by A. Mort and D. Godden, in which they analyzed over 2.000 publications indexed in world databases, covering the period from 1987 to 2010, it was possible to identify several characteristic

regularities. Most of the victims are between 20 and 39 years old. In most studies there was a clear majority of men, between 70% and 89%. The percentage of victims who suffered serious injuries ranged from 5% to 10% - less than 10% were admitted to hospital. About 90% of injuries concerned limbs. Some victims had life-threatening medical problems that resulted in long-term health consequences (Mort and Godden, 2011).

As part of their study, V. Schöffel, I. Morrison, I. Schöffel and T. Küpper analyzed over 500 separate articles which provided information on injuries, mortality and risk factors. They show that alpine (traditional) climbing is associated with a higher risk of injury than sport climbing, especially indoor climbing. Alpine and ice climbing are associated with more objective threats that may affect the climber's safety. General injury rates are low, nonetheless, fatal ones occur in all climbing disciplines. Altitude related illnesses and injuries also occur during climbing. The majority of injuries during sport climbing are upper extremity overuse injuries. During alpine climbing, injuries occur most often as a result of falls that affect the lower limb (Schöffel, Morrison, Schöffel, and Küpper, 2012).

An analysis of Spanish researchers carried out in the Aragon mountains, based on a retrospective study of records of rescue operations in 2010-2016, showed several important regularities. In 82% of cases, accident victims were men aged 50 to 59. Environmental problems, most often hypothermia, accounted for 36.6% of crisis situations. Heart problems accounted for 20.7% and digestive problems 12.8% of cases. Eighty-two percent of patients wandered or engaged in general mountain activities (other than climbing, canoeing, hunting or skiing) (Sierra Quintana, Martínez Caballero, Batista Pardo, Abella Barraca, and de la Vieja Soriano, 2017).

One of the most important challenges of emergency medicine is accidental hypothermia with cardiac arrest. For pre-hospital staff, the main goal is to lead the patient to the right destination where the right treatment will be given, without undue delay. For hospital staff, early information is necessary to assess the possibility of resuscitation with extracorporeal rewarming. A.W. Carlsen, N.K. Skjaervold, N.J. Berg and colleagues emphasize that good communication between pre-hospital and hospital staff can be crucial to optimizing patient treatment when dealing with severe hypothermia victims, especially in case of multiple victims (Carlsen, Skjaervold, Berg, Karlsen, Gunnarson, and Wahba, 2017).

As T. Darocha, S. Kosiński, A. Jarosz and their colleagues write, in case of severe accidental hypothermia (temperature < 28°C) and stage III / IV according to the Swiss staging system, standard methods may be ineffective and intensive treatment is required. In such cases, it turned out that extracorporeal membrane oxygenation (ECMO) is both effective and safe. The Department of Anaesthesiology and Intensive Care at the John Paul II Hospital in Cracow, Poland, established the Severe Accidental Hypothermia Center, which provides round-the-clock duty to consult and admit patients who need ECMO implantation to deeply re-heat hypothermia. The



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center is so far the only one in Poland and can admit patients from south-eastern Poland, it cooperates with all pre-hospital medical services, namely with 115 ambulances, Polish Medical Air Rescue and mountain rescue service (Darocha, Kosiński, Jarosz, Gazkowski, and Sadowski, 2015).

## **5. Summary and Concluding Comments**

This article presents selected, exemplary, representative and current scientific papers available in indexed world databases (Scopus, Elsevier, Web of Science). The intention of the authors of this article was to present the issue of mountain rescue, which is undertaken in non-profit organizations. A review of the currently available scientific literature, dedicated to mountain rescue on a global scale, allows to draw several conclusions that are answers to the research questions posed in the introduction.

First of all, the phenomenon and process of mountain rescue is based mainly in the field of operational activity on social and voluntary activities of the participants of non-profit organizations. Organizations participating in mountain rescue activities in a given country and geographical region are associated in the international non-profit organization called ICAR, which primarily performs opinion-forming, opinion-making and executive functions in relation to the mountain rescue process. It organizes scientific and practical conferences and symposia that set the directions of activity and development of non-profit mountain rescue organizations in individual countries and in the world. The results of scientific research are the basis for the organization and coordination of the training activities of ICAR and national associations. On the other hand, preventive, intervention and rescue effectiveness is the basis of economy and profitability in the management of non-profit organizations when they generate economic and social profits.

Secondly, the activities of mountain rescue organizations include various forms of conducting rescue operations, which include the following aspects: medical and therapeutic, logistics and transport, meteorological, technological, psychosocial and, last but not least, competence and training. They are scientifically and pragmatically explored by ICAR organizational entities, as well as by national mountain rescue organizations and by natural and legal persons cooperating with them in the field of mountain rescue and activities of supporting and related entities (other rescue services, medical entities).

Thirdly, mountain rescue is an interdisciplinary phenomenon and process that includes knowledge and skills in many fields and scientific disciplines. Among the sciences that significantly affect the practical functioning of mountain rescue, the following can be identified: medical sciences, health sciences, technical and engineering sciences as well as social sciences. As part of the aforementioned sciences and disciplines that occur in their theoretical-research areas, research is conducted on aspects of rescue operations, namely, technology for rescue and

transport, life functions of the human body in mountain accident conditions, human behavior during mountain activity, mountaineering competence of tourists and the competence of mountain rescuers in conducting interventions and mountain expeditions.

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**Notes:**

*1 Alternative names: German - Internationale Kommission für Alpines Rettungswesen (IKAR); French - Commission Internationale de Sauvetage Alpin (CISA). Due to the official languages in force in the discussed ICAR organization, you can find alternative entries for the acronym of this name: IKAR, IKAR-CISA*

*2 Polish: Górskie Ochotnicze Pogotowie Ratunkowe (GOPR)*