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SAFETY OF RESCUERS DURING AVALANCHE OPERATIONS

Abstract

The aim of this article is to analyze how the level of training of mountain rescue personnel affects their safety during avalanche rescue operations. The study was based on a survey conducted among members of the Polish Mountain Rescue Service (GOPR), completed by 36 respondents with various levels of experience. The author hypothesized that a higher level of training is linked to a higher level of safety during rescue missions. The article discusses how avalanches form, the main factors that trigger them, key aspects of rescue operation planning, and the importance of modern rescue equipment used in avalanche terrain. The results clearly show that mountain rescuers are aware of both terrain and weather-related risks. They recognize the importance of good organization, familiarity with rescue gear, and working in well-coordinated teams. Most respondents take part in avalanche training regularly, which improves their confidence and readiness for real missions. The findings support the hypothesis: regular training, field experience, and proper use of rescue equipment are essential for ensuring the safety of mountain rescuers working in avalanche-prone areas.

Keywords

mountain rescue, avalanche, safety

Introduction

An avalanche is a rapid, spontaneous movement of snow masses down a mountain slope, representing one of the most serious natural hazards in high-mountain areas. The mechanism of its formation is complex and results from the interaction of three main factors: snow, terrain shape, and atmospheric conditions[1].

The stability of the snow cover depends on its internal structure–especially the type, hardness, moisture, and layering of the snow[2]. The heterogeneity of this structure, caused by snow metamorphism and external factors (e.g., precipitation, wind, temperature fluctuations), leads to the formation of layers with varying cohesion and strength[3]. In particular, weakly bonded layers to the substrate form potential sliding planes for the upper snow layers. Among the terrain factors favoring avalanches, slope angle is the most important–the greatest risk occurs on slopes with an inclination of 30–45 degrees[4]. Geographic orientation and wind exposure are also significant, influencing the distribution and characteristics of snow deposits.

Meteorological conditions, such as heavy snowfall or rain, sudden temperature changes, and solar radiation, can disrupt the balance of the snow cover by increasing its mass, changing the physicochemical properties of the snow, or creating wet layers[5]. Human activity also plays an important role–over 90% of avalanches involving people are directly triggered by them[6].

Understanding the mechanisms leading to snow cover destabilization is crucial for avalanche risk assessment and effective safety management in mountainous areas.

Snow avalanches pose a serious threat to people in mountain regions. Statistics show an increase in avalanche incidents worldwide, linked to the changing climate of our planet, including global warming[7].

Increased interest in winter tourism and a growing number of people actively spending time in the mountains during winter mean that a larger number of potential victims may be present in avalanche-prone areas. As a consequence of these two factors, the number of avalanche accidents requiring organized rescue operations may consistently increase year by year.

Every avalanche accident poses a serious threat to the life and health of people within the danger zone, including rescuers[8]. Rescue operations in avalanche areas are

1 A. O'Baron, M. Clelland, *a Guide To Staying Safe In Avalanche Terrain*, 2012, p 1-5.

2 T. Kurzeder, H. Feist, *Lawinen. Risiko-Check fur Freerider*, Insbruck 2012, p. 58-65.

3 M. Kacperek, *Kochaj śnieg – unikaj lawin*, Kraków 2004, p. 38-43.

4 T. Kurzeder, H. Feist, *Lawinen. Risiko-Check fur Freerider*, Insbruck 2012, p. 17.

5 A. O'Baron, M. Clelland, *a Guide To Staying Safe In Avalanche Terrain*, 2012, p 52-58.

6 M. Kacperek, *Kochaj śnieg – unikaj lawin*, Kraków 2004, s. 20, p. 74-79.

7 J. A. Ballesteros-Cánovas et al., *Climate warming enhances snow avalanche risk in the Western Himalayas*, PNAS 2018; B. Berwyn, *How Climate Change May Influence Deadly Avalanches*, SCIAM 2021; H. Nabi, *How climate change worsens avalanches in the Himalayas,* Dialogue Earth 2023.

8 W. Andrusikiewicz , *Ratownictwo górskie w kontekście narażenia zawodowego*, conference materials, AGH 2023.

extremely risky and require specialized skills and proper preparation to minimize risks for those involved[9]. Currently, due to growing winter tourism and sports activity as well as increased avalanche risk, there is a need to assess safety and adequately prepare rescuers for operations in avalanche zones[10].

The issue of rescuer safety in avalanche terrain has always been a matter of balancing the shortest possible exposure time of rescuers in the avalanche area with conducting a thorough enough search to locate all buried victims[11]. In 2019, Albert Lunde and Christen Tellefsen conducted a retrospective study of avalanche accidents in Norway from 1996 to 2017, resulting in recommendations for the deployment and prioritization of rescue forces and resources at avalanche sites, taking into account the safety of both victims and rescuers on site[12]. The main conclusion of this study was that patients should receive appropriate treatment at the right place and time, and that the allocation of rescue resources should aim to reduce the time rescuers spend in avalanche terrain, especially in cases without confirmed victims.

Methodology

The aim of this article is to answer the research question: How do the experience and training level of mountain rescuers influence their awareness of hazards and their safety during rescue operations in avalanche terrain?

The author of this article formulates the following hypothesis: as the training level of mountain rescuers in avalanche rescue increases, their safety during rescue operations in avalanche terrain also improves.

The article also presents the main factors determining risks for rescuers, as well as safety strategies that can be applied to minimize dangers associated with rescue operations in avalanche areas. This analysis allows for a better understanding of safety requirements for rescuers and the identification of areas needing further research and the development of rescue practices.

A high level of training in avalanche rescue contributes to rescuers' skills and competencies in identifying and responding to hazards encountered during rescue operations in avalanche terrain. Experienced rescuers are better equipped to plan rescue actions, make appropriate decisions, and coordinate activities under difficult conditions in avalanche areas. Correct and proficient use of specialized rescue equipment can increase the efficiency of rescue operations by minimizing the time needed to locate and save buried victims, thereby reducing rescuers' exposure to danger while operating in avalanche terrain. High-quality training and regular skill

9 C. Van Tilburg et al., *Wilderness Medical Society Clinical Practice Guidelines for Prevention and Management of Avalanche and Nonavalanche Snow Burial Accidents,* Wilderness Medical Society 2024.

10 R. Szynowski (red.), *Ratownictwo górskie. Edukacja transgraniczna ratowników górskich w Polsce i na Słowacji,* Wydawnictwo Naukowe Akademii WSB, Dąbrowa Górnicza 2022, p. 153-168.

11 A. Kottmann et al., *Quality Indicators for Avalanche Victim Management and Rescue*, MDPI 2021

12 A Lunde, C. Tellefsen, *Patient and rescuer safety: recommendations for dispatch and prioritization of rescue resources based on a retrospective study of Norwegian avalanche incidents 1996–2017*, SJTREM 2019.

development are crucial for the effectiveness of rescue operations and for ensuring the safety of both rescuers and victims during avalanche rescue missions.

In this study, a diagnostic survey was selected as the research method. This is a research tool used to diagnose or assess specific problems, needs, or conditions of individuals or groups. The research technique is based on a questionnaire survey, which focuses on identifying problems or detecting certain features that may require further analysis or intervention. The research tool chosen was an online questionnaire created using Google Forms, which allowed easy access to the selected group of respondents and ensured their anonymity.

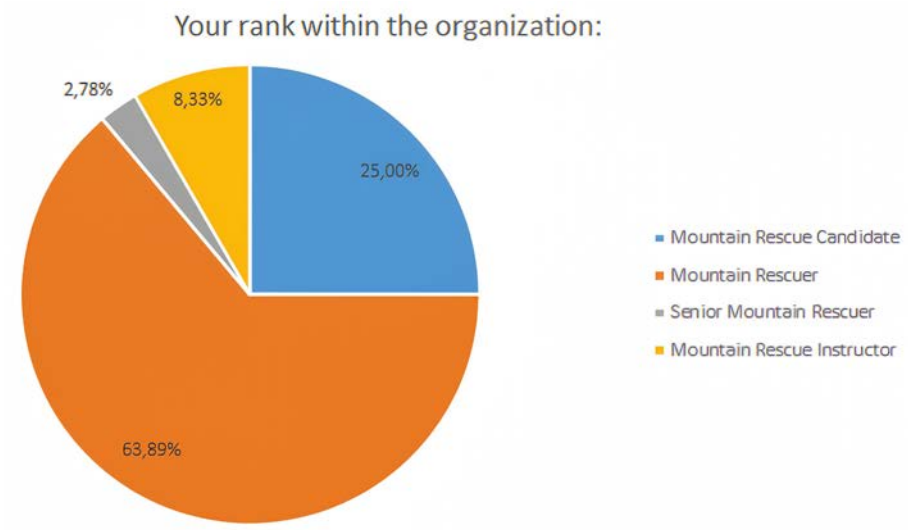
The respondents of this survey were mountain rescuers from the Karkonosze, Podhale, and Bieszczady Groups of the Mountain Volunteer Search and Rescue (polish: Górskie Ochotnicze Pogotowie Ratunkowe – GOPR). These organizations operate in avalanche-prone regions of Poland, and rescuers affiliated with these groups possess the greatest avalanche experience–both theoretical and practical. The questionnaire contained 11 questions aimed at answering the above research question.

Assessment of the Experience and Training of Mountain Rescuers in Avalanche Rescue

The study involved 36 mountain rescuers from all regional GOPR groups. Respondents answered questions in a questionnaire created using the Google Forms tool.

The largest group of respondents (75%) consisted of experienced rescuers: mountain rescuers (63.9%), instructors (8.3%), and senior mountain rescue instructors (2.8%). Candidates for mountain rescuers made up 25% of the participants in the study.

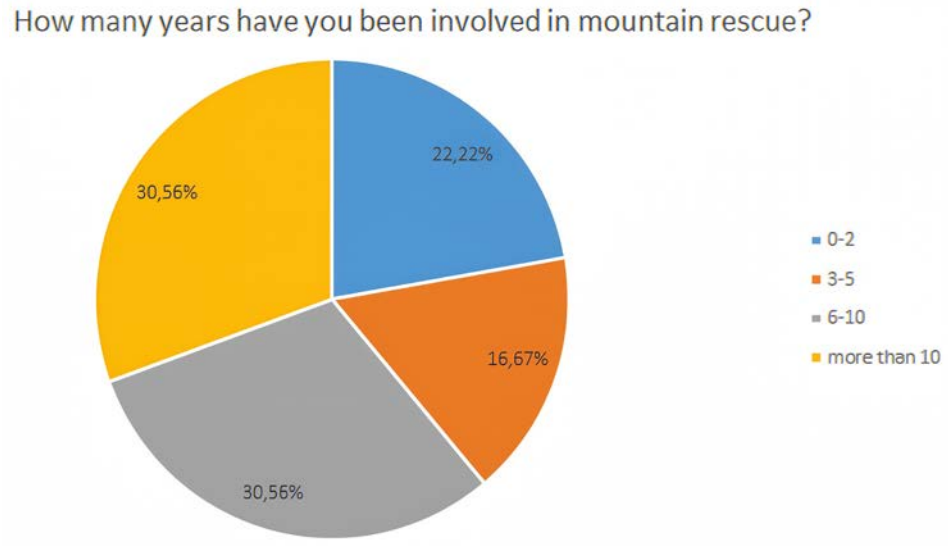
Chart 1. Rank within the organisation



Source: author's own work.

Over 30% of the respondents were rescuers with more than 10 years of experience. The same proportion had more than 5 years of experience. Rescuers with up to 2 years and up to 5 years of experience in mountain rescue accounted for 22.2% and 16.7% of the survey participants, respectively.

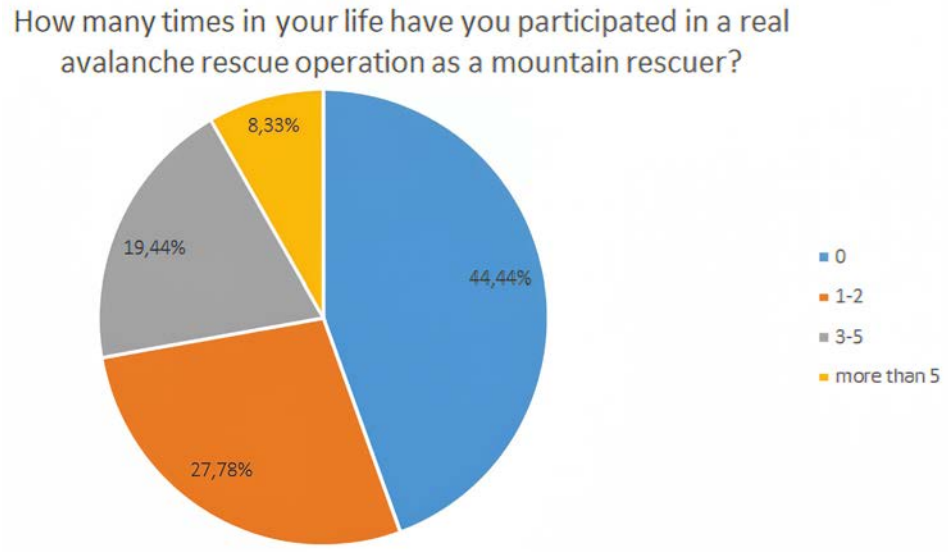
Chart 2. Length of Service in Mountain Rescue



Source: author's own work.

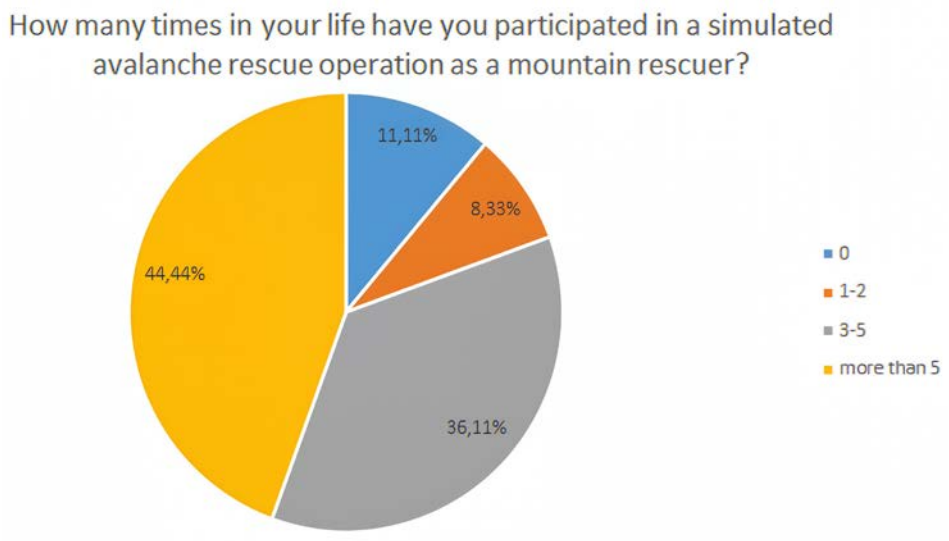
Due to the rarity of avalanche occurrences, nearly 45% of respondents have never had the opportunity to participate in real avalanche rescue operations as mountain rescuers. However, more than half have taken part in such operations at least once. a total of 8.3% of respondents reported participating in more than five real avalanche rescue operations. Nevertheless, the vast majority of rescuers involved in the study have taken part in simulated avalanche rescue scenarios during training exercises.

Chart 3. Participation in Real Avalanche Rescue Operations



Source: author's own work.

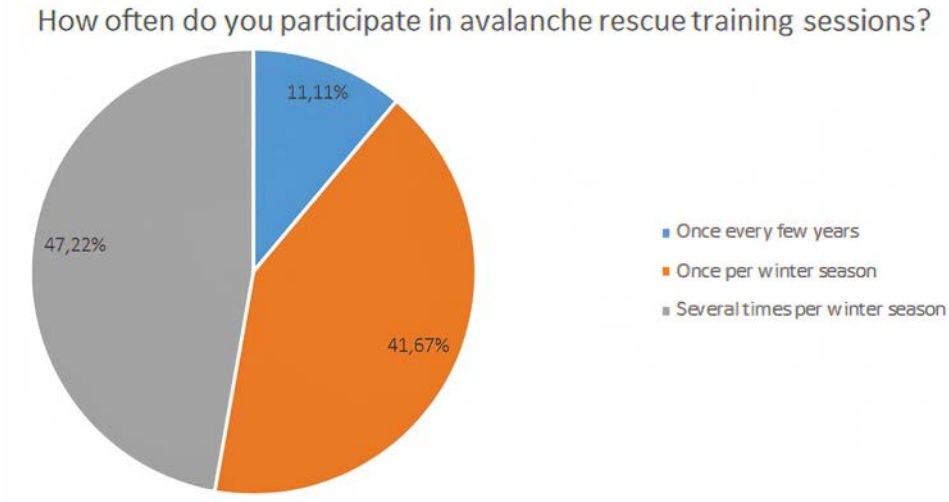
Chart 4. Participation in Simulated Avalanche Rescue Operations



Source: author's own work.

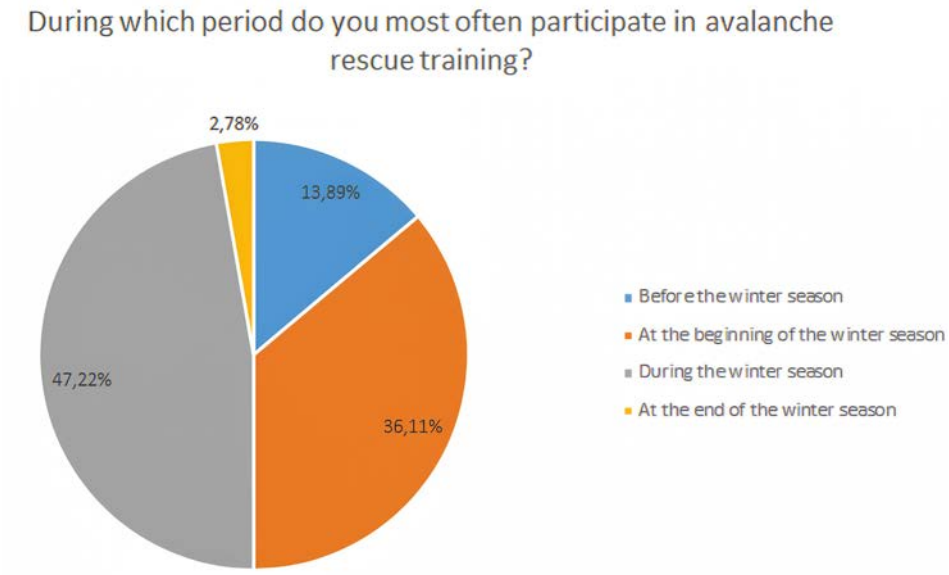
The vast majority of surveyed rescuers (88.9%) declare that they participate in avalanche rescue training at least once per winter season, with more than half of them refreshing this training multiple times throughout the season. Most of the training sessions take place at the beginning and during the winter season.

Chart 5. Frequency of Avalanche Rescue Training



Source: author's own work.

Chart 6. Timing of Avalanche Rescue Training Sessions



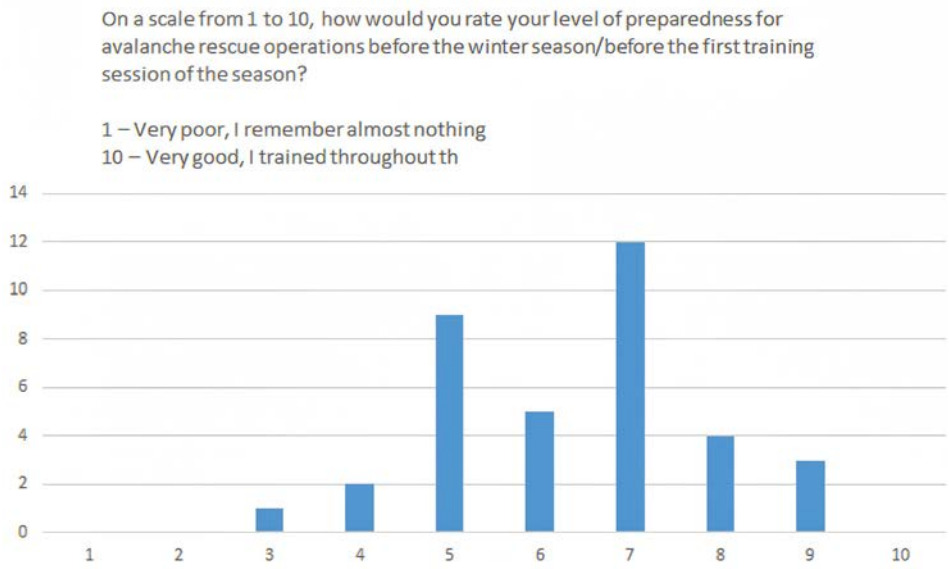
Source: author's own work.

Self-Assessment of Rescuers' Training

Respondents were asked to evaluate their level of preparedness for avalanche rescue operations before the winter season and before the first avalanche training of the season. The assessment was conducted using a 10-point scale, where 1 indicated very poor preparedness and 10 indicated very good preparedness.

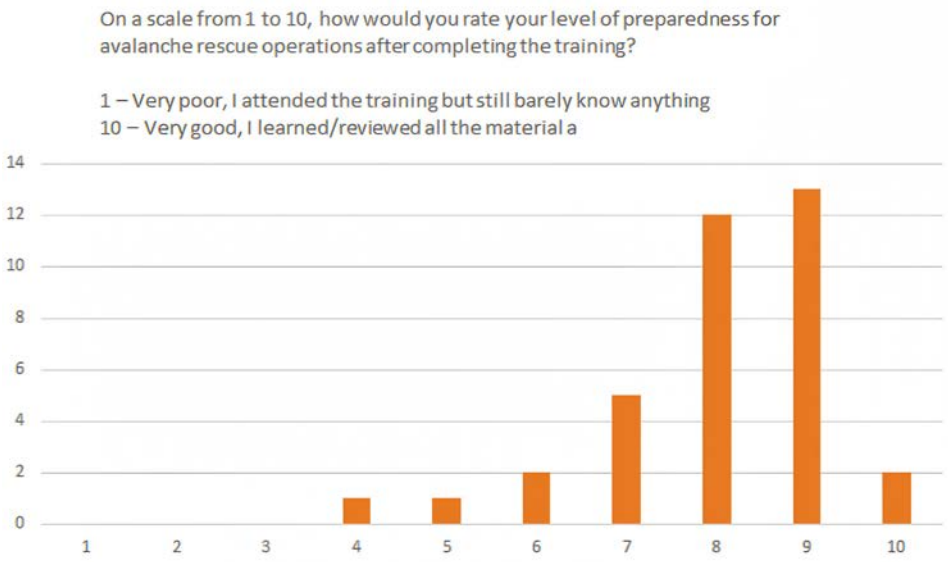
Next, the respondents were asked to assess their level of preparedness for avalanche rescue operations after completing the training, using the same 10-point scale.

Chart 7. Level of Preparedness Before the Winter Season



Source: author's own work.

Chart 8. Level of Preparedness After Training



Source: author's own work.

It is clearly noticeable that attending training before or during the season significantly increases rescuers' level of preparedness for avalanche rescue operations. It is worth noting that a large proportion of rescuers report a decent level of training and readiness (6–9) even before their first training session of the winter season. This reflects their experience and participation in similar trainings over previous years. However, even these experienced rescuers enhance their knowledge, skills, and confidence through regular annual training refreshers.

Rescuers' Opinions on Factors Affecting Safety During Avalanche Rescue Operations

The surveyed rescuers were presented with a series of questions asking them to assess the impact of various factors on safety during avalanche rescue operations. These questions were divided into two groups: factors negatively affecting rescuers' safety and factors positively influencing their safety.:

1. To what extent do the following factors NEGATIVELY affect the safety of rescuers during avalanche rescue operations?
   - strong wind
   - rainfall
   - snowfall
   - intense sunlight
   - night work
   - steep slope gradient
   - difficult access to the incident site
   - working with unfamiliar people
   - working with unknown equipment
   - lack of adequate rescuer training
2. To what extent do the following factors POSITIVELY affect the safety of rescuers during avalanche rescue operations?
   - absence of wind
   - good visibility
   - working during the day
   - working with familiar people
   - working with equipment known to me
   - good rescuer training
   - rescuers equipped with avalanche transceivers
   - well-organized avalanche rescue operation
   - marking the avalanche area with flags
   - keeping a register of people working in the avalanche zone
   - identification of rescuers with numbered armbands

For both questions, a 5-point scale was used to assess the respondents' awareness of factors affecting safety during avalanche rescue operations:

1 – do not affect at all
2 – have some effect, but are not significant
3 – no opinion
4 – have a strong effect
5 – have a very strong and significant effect
The results of the study are presented in the tables below:

Table 1. Assessment of Factors Negatively Affecting Safety

To what extent do the following factors NEGATIVELY affect the safety of rescuers during avalanche rescue operations?					
FACTOR	**1**	**2**	**3**	**4**	**5**
strong wind	0	2	3	15	16
rainfall	0	1	3	18	14
snowfall	1	4	2	11	18
intense sunlight	0	6	8	16	6
night work	0	6	4	13	13
steep slope gradient	0	1	5	9	21
difficult access to the incident site	0	2	4	12	18
working with unfamiliar people	0	10	11	9	6
working with unknown equipment	2	6	8	10	10
lack of adequate rescuer training	1	1	3	10	21

Source: author's own work.

Table 2. Assessment of Factors Positively Affecting Safety

To what extent do the following factors POSITIVELY affect the safety of rescuers during avalanche rescue operations?					
FACTOR	**1**	**2**	**3**	**4**	**5**
absence of wind	0	8	3	10	15
good visibility	0	0	2	19	15
working during the day	0	3	5	15	13
working with familiar people	0	3	5	11	17
working with equipment known to me	0	2	3	14	17
good rescuer training	0	1	0	10	25
rescuers equipped with avalanche transceivers	0	0	3	5	28
well-organized avalanche rescue operation	0	0	1	5	30
marking the avalanche area with flags	1	3	6	12	14
keeping a register of people working in the avalanche zone	0	2	5	12	18
identification of rescuers with numbered armbands	0	4	7	13	12

Source: author's own work.

The third question asked respondents to express their opinion on the following statements:

- Avalanche rescue training only needs to be completed once in a lifetime.
- Avalanche rescue training should be conducted regularly, preferably before or at the beginning of the winter season.
- The quality and type of equipment do not matter during an avalanche rescue operation.
- Using equipment familiar to the rescuer increases the safety of rescuers on the avalanche site.
- Weather conditions during an avalanche rescue operation have a significant impact on safety at the avalanche site.
- Assigning one or more people to continuously observe the slope and avalanche area increases the safety of rescuers working there.

- The use of modern avalanche transceivers by rescuers increases their safety.
- The occurrence of a secondary avalanche affecting rescuers is very unlikely and can be neglected in risk assessment.
- If the operation leader assesses that entering the avalanche site is too dangerous, the rescue operation should be postponed until conditions improve.
- Good planning and management of the avalanche rescue operation by an experienced person increases the safety of rescuers.
- Thoroughly reviewing the avalanche bulletin before the rescue operation increases the safety of rescuers.

For this question, a 5-point Likert scale was used to assess the extent to which rescuers agreed with the given statements:

1 – Strongly disagree
2 – Rather disagree
3 – No opinion
4 – Rather agree
5 – Strongly agree

Table 3. Respondents' opinion on the submitted statements

Please indicate the extent to which you agree with the following statements regarding rescuer safety on the avalanche site:					
STATEMENT	**1**	**2**	**3**	**4**	**5**
Avalanche rescue training only needs to be completed once in a lifetime.	34	1	0	0	1
Avalanche rescue training should be conducted regularly, preferably before or at the beginning of the winter season.	0	0	0	7	29
The quality and type of equipment do not matter during an avalanche rescue operation.	18	3	1	7	7
Using equipment familiar to the rescuer increases the safety of rescuers on the avalanche site.	0	0	2	6	28
Weather conditions during an avalanche rescue operation have a significant impact on safety at the avalanche site.	0	0	1	7	28
Assigning one or more people to continuously observe the slope and avalanche area increases the safety of rescuers working there.	0	1	1	8	26
The use of modern avalanche transceivers by rescuers increases their safety.	0	0	1	6	29
The occurrence of a secondary avalanche affecting rescuers is very unlikely and can be neglected in risk assessment.	28	4	1	1	2
If the operation leader assesses that entering the avalanche site is too dangerous, the rescue operation should be postponed until conditions improve.	2	2	1	15	16
Good planning and management of the avalanche rescue operation by an experienced person increases the safety of rescuers.	0	0	2	5	29
Thoroughly reviewing the avalanche bulletin before the rescue operation increases the safety of rescuers.	0	2	4	6	24

Source: author's own work.

Based on the conducted analysis, it can be concluded that the awareness of mountain rescuers regarding safety during operations carried out in avalanche terrain is at a high level. The survey results clearly indicate that the rescuers are able to accurately identify both factors that promote and threaten the safety of rescue operations under avalanche conditions. The majority of respondents disagree with the statement that attending avalanche training once in a lifetime is sufficient, which demonstrates a widespread understanding of the necessity for regular skills improvement and knowledge updating–especially prior to the winter season.

Respondents place great importance on meteorological conditions and terrain configuration, recognizing them as significant determinants of risk. a clear majority of participants acknowledge the importance of proper planning, management of the rescue operation by experienced leaders, and the use of modern technologies (e.g., avalanche transceivers) as elements that significantly enhance safety. Furthermore, rescuers are aware of the threat posed by secondary avalanches and are willing to suspend operations if the risk is deemed too high–indicating a rational approach to hazard assessment.

The conclusions from the analysis clearly show that key factors for rescuer safety include: high-quality training, familiarity with equipment, effective communication within the team, and continuous monitoring of weather conditions and avalanche bulletins. Such attitudes and beliefs align with current safety standards in high-mountain rescue operations and form the foundation of effective and safe rescue interventions in avalanche terrain.

Conclusions

This study characterized the mechanism of avalanche formation and the factors influencing their initiation. It was emphasized that avalanches are dynamic and multifactorial phenomena, whose occurrence is determined by, among others, the structure of the snow cover, slope angle, meteorological conditions (wind, precipitation, sunlight), and human activity. Special attention was given to the impact of weather and environmental variability as risk factors for both bystanders and the rescuers themselves. In the context of safety, it was demonstrated that secondary avalanches pose a real threat to search and rescue teams, which is also confirmed by the survey responses.

Analyzing the above data allows us to answer the initial research question: How do the experience and training level of mountain rescuers affect their awareness of hazards and their safety during rescue operations in avalanche terrain?

The analysis shows that rescuer safety during avalanche operations results from their knowledge, experience, equipment familiarity, and good team organization.

Based on responses from 36 mountain rescuers, it can be concluded that their training level and awareness are high. As many as 88.9% of participants declare attending avalanche training at least once per season, with over half participating

multiple times. Before the season, rescuers assess their readiness as moderate, but after training, their confidence and competence noticeably increase.

The survey results clearly indicate that rescuers::

- are aware of hazards related to adverse weather and terrain conditions (e.g., strong wind, precipitation, slope steepness),
- appreciate the importance of good organization, equipment knowledge, and working with an experienced team,
- recognize the need for regular training and are willing to suspend operations under extremely dangerous conditions.

The vast majority of respondents reject statements suggesting that a single training or random equipment is sufficient for safe operation. Almost unanimously, they agree that modern avalanche transceivers, proper organization, and knowledge of avalanche bulletins significantly enhance safety.

The hypothesis was formulated that as the level of rescuers' training in avalanche rescue increases, their safety during rescue operations improves. The author also referred to retrospective studies by Lunde and Tellefsen (2019), which emphasized the need to minimize the time rescuers spend in hazard zones to enhance their safety. The analysis was based on survey data collected from GOPR rescuers with significant avalanche operation experience in Poland.

The research hypothesis was confirmed–high training levels significantly reduce risk for rescuers. Additionally, regular training, conscious decision-making, and the use of modern technical equipment form the foundation for safe and effective rescue operations in avalanche conditions.

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