The snow avalanche event analysis – a proposal of the new method in the example of the Giant Mountains

Authors' Contribution:
- ☑ **A** Study Design
- ▭ **B** Data Collection
- 📈 **C** Statistical Analysis
- ▤ **D** Manuscript Preparation
- ⚙ **E** Funds Collection

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Abstract

Background and Study Aim: The snow avalanches occur in very high mountains like Himayalas where the avalanche occurred on Pumori killing 19 people on 04.25.2015 or in high mountains like the Apennines where the avalanche appeared on Gran Sasso d'Italia and caused 29 deaths on 01.18.2017. They can also appear in not high mountains. The aim of this study is answer the question: 'What are the most prone avalanche areas in the Giant Mountains'? The hypothesis is: 'The most prone avalanche area in the Giant Mountains is the Biały Jar'.

Material and Methods: The paper contains the proposal of the new method – the snow avalanche event analysis (SAEA). This method consists of 6 steps: studying the avalanches; collecting the global data; gathering the local data; comparing the data; assessing the risk; computing the effects. To analysis authors acquired information from secondary sources on the number of tourists visiting the Karkonoski Park Narodowy in 2010-2016 and the Krkonošský národní park in 2012-2015 and data on the occurrence of snow avalanches in the Giant Mountains in the years (1655 to 2018).

Results: The most prone snow avalanche areas in the whole Giant Mountains, in the Polish and Czech part, are (the risk indicators in brackets): the Obří důl (0.002515%), the Dlouhý důl (0.002260%), the Biały Jar (0.001702%) and the Kocioł Małego Stawu (0.001560%).

Conclusions: Authors falsified the formulated hypothesis: 'The most prone avalanche area in the Giant Mountains is the Biały Jar'. We applied positively the new method – SAEA – in the example of the Giant Mountains (Karkonosze).

Key words: Górskie Ochotnicze Pogotowie Ratunkowe • Horska služba ČR • Karkonoski Park Narodowy • Karkonosze • Krkonoše • Krkonošský národní park • mountain rescue service • National Park

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Giant Mountains (Karkonosze, Krkonoše) – *noun* the highest mountain range of the Sudetes located in the south-west of Poland and in the north of the Czech Republic. The total area of the Giant Mountains is 639 km² [37].

Karkonosze Group of the Mountain Volunteer Search and Rescue (Grupa Karkonoska Górskiego Ochotniczego Pogotowia Ratunkowego – GK GOPR) – *noun* GOPR is a public benefit organization which task is a rescue of human life in Polish mountains. The Karkonosze Group is one of 7 GOPR groups which functions in the Western Sudetes, including the Giant Mountains [11, 14, 51].

Mountain Rescue Service of the Czech Republic (Horska služba ČR) – *noun* a public benefit organization which task is a rescue of human life in Czech mountains. It operates in 7 districts, especially in the Giant Mountains [52].

Karkonosze National Park (Karkonoski Park Narodowy – KPN) – *noun* national park located in the Polish part of the Giant Mountains. It covers an area of 59,51 km² [43, 45].

Krkonoše National Park (Krkonošský národný park – KRNAP) – *noun* the national park located in the Czech part of the Giant Mountains. It covers an area of 550 km² (with a buffer zone) [43, 54].

Snow avalanche – rapid downslope movement of a mix of snow and ice [1-4].

Snow avalanche event (SAE) – the rapid movement of large masses of snow down the slope to a distance of at least 50 meters which causes death and / or suffering of people and animals [7, 8, 15-18, 50].

Risk – probability of occurrence of an adverse event with its effects in a given time [29, 30].

EM-DAT – in 1988, the **Centre for Research on the Epidemiology of Disasters (CRED)** launched the Emergency Events Database (EM-DAT). EM-DAT was created with the initial support of the **World Health Organisation** and the **Belgian Government**. The main objective of the database is to serve the purposes of **humanitarian**

INTRODUCTION

The avalanche is defined by Spusta et al. [1, 2] and Niemiec [3] as 'Rapid downslope movement of a mix of snow and ice'. Their definition of avalanche is similar to the notion of snow avalanche formulated by the EM-DAT but Spusta et al. [1, 2] and Niemiec [3] precise that the rapid downslope movement concerns only snow (not snow and ice) and its distance is minimum 50 metres [4].

The snow avalanches occur in very high mountains like Himayalas where the avalanche occurred on Pumori killing 19 people on 04.25.2015 [5, 6] or in high mountains like the Apennines where the avalanche appeared on Gran Sasso d'Italia and caused 29 deaths on 01.18.2017. They can also appear in not high mountains [7, 8].

On 03.20.1968, the snow avalanche appeared in Biały Jar in the Giant Mountains which are not high. It killed 19 persons (13 Russians, 4 Germans and 2 Poles). The avalanche was over 800 meters long, 80 wide, and her forehead was 30 meters high. The areas where it descent – the Biały Jar – is located in the Giant Mountains above the upper forest border. Here, at an altitude of 1234 m a.s.l., the Silesian Way (black walking trail) connects the lower and upper station of the lift to the Kopa peak (1377 m a.s.l) and encounters a yellow walking trail (the summer route) that leads towards the Strzecha Akademicka hostel. The Biały Jar is a nodal niche where the Złoty Potok begins. On its upper edge, huge snow overhangs form. The inclination of its slopes, of which almost half of the surface is covered with scarce grassland vegetation or is completely devoid, is 30-39°. The grounds of the Biały Jar slopes consist of rubble-sand with a mean thickness of 1.5 m, and locally even 2-3 m, which is unusual for the Giant Mountains slopes with such inclination. The mentioned factors cause significant intensification on the slopes of the Biały Jar of phenomena such as landslide on July 1997 or snow avalanche in 1968 [9-14] .

According to [11, 14], Biały Jar has long been considered an area especially endangered by avalanches. In the opinion of [Staffa i inni], the Biały Jar is 'one of the most avalanche and dangerous places in the Polish mountains'[15, 16, 7, 17, 8, 18].

The aim of this study is answer the question: 'What are the most prone avalanche areas in the

Giant Mountains'? The hypothesis is: 'The most prone avalanche area in the Giant Mountains is the Biały Jar'.

MATERIAL AND METHODS

In order to answer the research question and verify the hypothesis, we created and applied the snow avalanche event analysis (SAEA). It is the new method basing on the method of proof that uses deductive reasoning which is appropriate to analytical thought activities. The SAEA consists of 6 steps:

Step 1 – studying the avalanches. We studied the literature and avalanche cadaster for the examined area in Giant Mountains and the field work [17, 18]. We slightly modified the definition of the snow avalanche event (SAE) [15, 16, 7, 17, 8, 18]. After modification we described it as 'the rapid movement of large masses of snow down the slope to a distance of at least 50 meters which causes death and / or suffering of people and animals'. We searched the Scopus database with combinations of keywords: 'snow avalanche' AND 'mountain rescue service' [19]. We obtained only 21 results. We excluded 20 of them because only one concerned the snow avalanche hazard of the Krkonoše National Park in the Czech Republic [20].

Step 2 – collecting the global data. We searched the EM-DAT (see glossary) database with the keyword 'avalanche' to build the table with events that occurred from 1900 to 2018 in the World. We chose 'Advanced search' from the database search options. We selected the following 'Search criteria': 'Period' – from 1900 to 2018; 'Location' – continent (Africa, Americas, Asia, Europe, Oceania); 'Group/Subgroup/Type/Subtype': Natural/Geophysical/Mass movement (dry)/ Avalanche and Natural/Hydrological/Landslide/ Avalanche; 'Group results by': Year, Disaster group, Disaster subgroup, Disaster type, Disaster subtype, Continent, Region, Country name [4]. Obtained data with search results; including ISO, Occurrence, Total deaths, Injured, Affected, Homeless, Total Affected, Total damage ('000 $); were exported from CSV to the spreadsheet to aggregate avalanches according to the continent.

Step 3 – gathering the local data. We obtained information from secondary sources on the number of tourists visiting the Karkonoski Park Narodowy

(KPN) in 2010-2016 [21] and the Krkonošský národní park (KRNAP) in 2012-2015 [22]. We used data on the occurrence of snow avalanches in the Giant Mountains in the years 1655-2008 [9, 23, 15, 16, 14, 17, 7, 8, 18]. A list of events recorded by chroniclers and rescuers of Polish and Czech public benefit organizations – the Karkonosze Group of the Mountain Volunteer Search and Rescue (Grupa Karkonoska Górskiego Ochotniczego Pogotowia Ratunkowego – GK GOPR) and the Mountain Rescue Service of the Czech Republic (Horska služba ČR), we extended with our own observations of events from the next 10 years which were also mentioned in internet websites[24-28].

Step 4 – comparing the data. We compared the occurrence of snow avalanches in the Giant Mountains in the years 1655-2018, with the SAE criterion and contemporary avalanche cadaster to reject phenomena which not fulfilled the SAE definition or occurred beyond. We also compared the EM-DAT data with the list of events recorded by chroniclers and rescuers.

Step 5 – assessing the risk. We used the risk assessment methodology, understood as the probability of occurrence of an adverse event with its effects in a given time [29, 30]. We determined the probability by calculating the frequency of occurrence (fo), according to the formula: fo = (number of SAE in an avalanche prone area / examined time interval) ×100% [15-17, 7, 8, 18].

Step 6 – computing the effects. We calculated effects in the spreadsheet, summing up the total number of victims in a given avalanche prone area (deaths and affected), and dividing it by the sum of the average monthly number of tourists

visiting KPN / KRNAP for tested avalanche prone area in the examined period of time in the months: January-April and November-December. We obtained a risk indicator for a given examined avalanche prone area, multiplying the probability each time by the effects of the occurrence of SAE in the examined avalanche prone area – the higher the risk, the more avalanche prone area is [15-17, 7, 8, 18].

Snow avalanches

The snow avalanches are caused by the heavy snowfalls on steep slopes yielding to the pull of gravity [31]. Effects of snow avalanches, especially injuries and damages are related to the expansion of settlement, land use and infrastructure into areas which are at risk from snow mass instability. The rising popularity of winter sports constitutes a particular problem for emergency services as to how to maintain public safety without placing unnecessary restrictions on access [32]. Anyone who leaves the designated route, goes to an area that is not protected from avalanche danger. It means that outside trails and in high-altitude areas it may theoretically descend anytime an avalanche [33, 8].

Besides the snow avalanche, the EM-DAT defines broader the avalanche as 'A large mass of loosened earth material, snow, or ice that slides, flows or falls rapidly down a mountainside under the force of gravity'. As we can see in the table 1, from 1900 to 2018 by the EM-DAT were registered 115 avalanches. They were entered only disasters that fulfilled at least one of the following criteria: 10 or more people deaths; and/or 100 or more people affected/injured/homeless; and/or declaration by the country of a state of

action at national and international levels. The initiative aims to rationalise decision making for **disaster preparedness,** as well as provide an objective base for **vulnerability assessment and priority setting.** EM-DAT contains **essential core data** on the occurrence and effects of over **22,000 mass disasters** in the world from **1900 to the present day.** The database is compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies [*EM-DAT website*].

EFPA – "extreme form of physical activity are extreme sports, often classified according to the environment in which they are performed (water, land, air), extreme form of physical recreation as well as gainful activity or voluntary service, and all varieties of physical activity that meet at least one classification criterion of the feature associated either with extreme risk of injury or death, or extreme body burden with high level of effort, or extreme coordination difficulty" [58, p. 19].

Table 1. Avalanches (snow and debris) registered by the EM-DAT in the years 1900-2018 according to the number of events.

Continent	Events	Deaths	Affected	Damages (in ,000 US$)
Asia	67	3787	92553	53000
Europe	40	1425	14927	777489
North America	4	150	22	0
South America	4	83	154	0
Africa	0	0	0	0
Oceania	0	0	0	0
Total	**115**	**5445**	**107676**	**830489**

Source: study on the basis of [4].

emergency; and/or an appeal for international assistance. When figures are missing, some secondary criteria such as significant damage or significant disaster are also taken into account. According to EM-DAT, snow avalanches killed over 5.5 thousand people and affected over 100 thousand persons. Avalanches caused over 800 million US$ damages (in current prices) [4].

The most deadly were Marmolada avalanches were noted in Dolomites in Italy in 1916. They killed approx. 10000 people [34]. However, the Marmolada avalanches were not recognized by the EM-DAT database. Also, the snow avalanche in the Giant Mountains in 1968 wasn't noted by the EM-DAT [8]. Moreover, in the database there are registered the avalanches without separation on their types, thus, the EM-DAT distinguishes the snow and debris avalanches[35] only theoretically in definitions, not in the registry.

Before Z. Piepiora and Sikora studies [7, 8 15-18], similar case study did [5]. They presented the snow avalanche hazard map of the Czech part of the Giant Mountains. They prepared the map using historical records of 1132 avalanches which occurred during 54 years period and. To create the map they used state-of-the-art modeling of avalanche propagation and the spatial distribution of potential avalanche source areas. However their map provided reliable and easy to understand information for the Mountain Rescue Service, mountain tourists and for land use managers to identify areas where new avalanche paths may develop under favorable conditions, their study was done only for the Czech part of the Giant Mountains and for the short, 54 years period.

Characteristics of the examined area

The Giant Mountains (Karkonosze) are located in the western part of the Sudetes (Sudety) and are the highest Sudetic mountain range [36-42]. The total area of the Giant Mountains (Figure 1) is 639 km^2. There is 454 km^2 on the Czech side, i.e. 71.05% of the area of these mountains, and 185 km^2 on the Polish side (only 28.95%) [43].

Due to its unique natural values, 59,51 km^2 of the Giant Mountains is under strict protection as part of the Karkonosze National

Figure 1. Panorama of the Giant Mountains (Karkonosze)
Source: picture by Zbigniew Piepiora.

Park (Karkonoski Park Narodowy – KPN). The KPN cover area is 130,93 km². On the Czech side, the Krkonoše National Park (Krkonošský národný park – KRNAP) was created with an area of 550 km² (with a buffer zone) [44-47]. The average monthly number of tourists that visited KPN and KRNAP is presented in the Figures 2 and 3.

The occurrence of snow avalanches in the Giant Mountains is associated with: slope slopes greater than 30°, grassy and rocky slopes, covering a large snow cover on two flattenings located between the inner Czech Ridge and the Silesian Ridge [1, 2]. In addition to the Biały Jar, the areas threatened by snow avalanches in the Polish part of the Giant Mountains are: the Czarny Kocioł Jagniątowski,
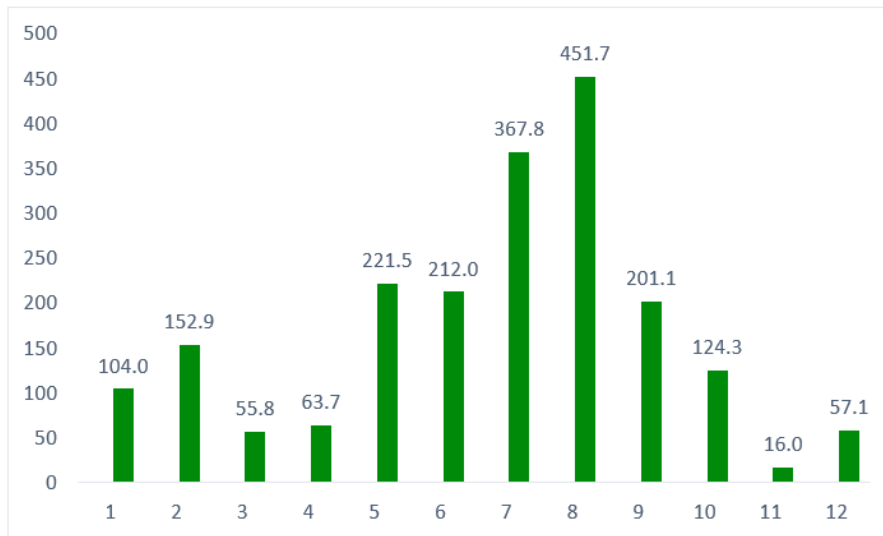
Figure 2. The average monthly number (1 to 12) of tourists that visited KPN in the years 2012-2015 in thousands with underestimation.

Source: study on the basis of [8, 21].
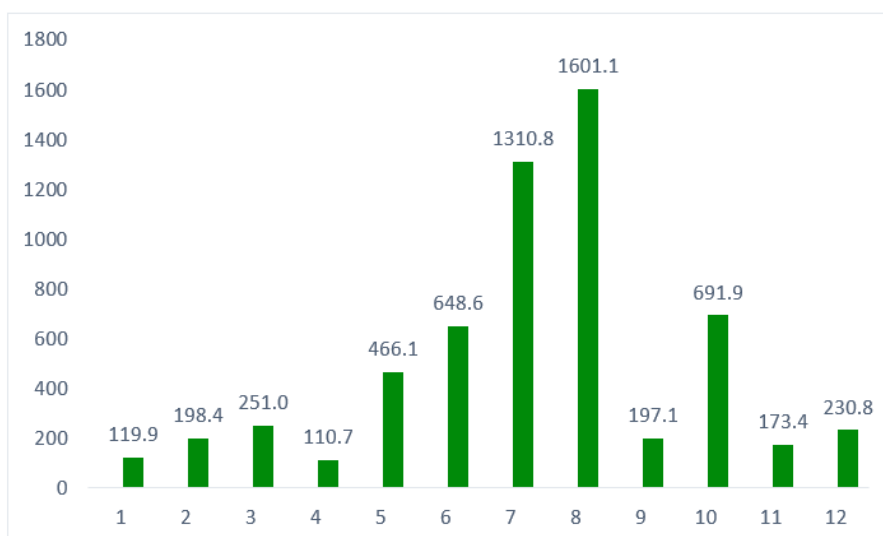
Figure 3. The average monthly number (1 to 12) of tourists that visited KRNAP in the years 2012-2015 in thousands with underestimation and including cars and bicycles

Source: study on the basis of [22].

the Kocioł Łomniczki, the Kocioł Małego Stawu, the Kocioł pod Małym Szyszakiem, the Kocioł Smogorni, the Kocioł Wielkiego Stawu, the Łabski Kocioł, the Mały Śnieżny Kocioł, the northern slope of the Łabski Szczyt, the Szrenicki Kocioł, the Wielki Śnieżny Kocioł. In the Czech part of the Giant Mountains, these are: the Dlouhý důl, the Důl Bílého Labe, the Labský důl, the Modrý důl, the Obří důl, the Kotelní jámy. Both on the Polish and Czech side, in the winter season, there is an average of 20-25 snow avalanches, which together gives about 50 [48, 49, 17, 50, 18].

After analyzing the occurrence of snow avalanches in the Giant Mountains in the years 1655-2018, we rejected phenomena that did not fulfill the SAE criterion or occurred outside of contemporary avalanche cadaster [1, 2, 23]. The time range necessary to calculate the probability was reduced to 1700-2018 (318 years).

We determined the probability by calculating the frequency of occurrence (in part), according to the formula: = (number of SAE's in a given snow avalanche prone area / 318) ×100%.

RESULTS

As we can see in the table, the snow avalanches killed 100 people and affected 166 persons. Table 2 shows that most people died under avalanches in the Biały Jar – 22 persons. The largest number of people were affected in Labský důl 39 persons.

Table 2. Avalanches, SAE's and affected registered in the Giant Mountains in the years 1655-2018 according to the number of SAE's.

Area	Avalanches	SAE's	Deaths	Afftected	Contemporary avalanche cadastre
Obří důl	14	12	18	25	Yes
Kocioł Małego Stawu	14	11	4	18	Yes
Dlouhý důl	12	10	12	8	Yes
Modrý důl	9	7	6	6	Yes
Kocioł Łomniczki	8	5	5	7	Yes
Wielki Śnieżny Kocioł	5	5	8	8	Yes
Biały Jar	7	4	22	14	Yes
Důl Bílého Labe	5	4	1	8	Yes
Labský důl	5	4	4	39	Yes
Kotelní jamy	5	3	2	13	Yes
Szrenicki Kocioł	2	1	2	1	Yes
Zelený důl	2	2	5	1	No
Bönischovy boudy*	1	1	0	2	No
Čerstvá voda	1	1	1	1	No
Dolní Dvůr	1	1	0	2	No
Dolní Maršov	1	1	0	4	No
Horní Lánov	1	1	2	0	No
Kocioł Wielkiego Stawu	1	1	0	1	Yes
Sklenářovice	1	1	8	7	No
Vlčí jáma	1	1	0	1	No
Total	**96**	**76**	**100**	**166**	**-**

* snowfall from the roof of the Primavera hostel.

Source: study on the basis of [7-9, 15-18, 23-28, 50].

Snow avalanches occurred in the months of November, December and January-April. After comparing the data that served to prepare tables 1 and 2, we noted that neither of snow avalanches recognized in the table 2 was registered in EM-DAT. The avalanches evidenced in EM-DAT occurred beyond the Giant Mountains.

As a result of the analysis of the appearance of SAE in the Giant Mountains, we described the most snow avalanche prone areas: the Biały Jar, the Dlouhý důl, the Důl Bílého Labe, the Kocioł Łomniczki, the Kocioł Małego Stawu, the Kocioł Wielkiego Stawu, the Kotelní jámy, the Labský důl, the Modrý důl, the Obří důl, the Szrenicki Kocioł, the Wielki Śnieżny Kocioł (Table 2).

We determined effects, summing the total number of victims in a given snow avalanche prone area, i.e. deaths and casualties, and dividing by the sum of the average monthly number of tourists visiting KPN and KRNAP in 2012-2015 in the months in which he registered the occurrence of SAE: January-April and November-December.

In the case of KPN, we applied the data from sale points of entrance tickets for 2010-2016 which totaled 913.2 thousands [21]. Due to the fact that there are no admission tickets at KRNAP, we used the research on tourism in the years 2012-2015 [22]. In order for the data for both parks to become comparable, we shortened the analysis period for KPN from 2010-2016 to 2012-2015. The number of entrance tickets for 2012-2015 for KPN totaled 926 025 and adequate number for KRNAP 984 412. It was a much shorter period (4 years) than the period of SAE occurrence (318 years). Unfortunately, we did not have access to any other data.

As we can see in the tables 3 and 4, we estimated indicators by which we multiplied the monthly average number of tourists visiting KPN (by 2.159769) and KRNAP (by 6.095007). We did so because the total number of tickets sold to KPN was over two times lower than the estimated 2 million visitors [56, 57]. In the case of KRNAP, the number of respondents was more than six times lower than the estimated 6 million visitors [54, 55]. Next, we excluded tourists using

Table 3. Tourist traffic in the Karkonosze National Park and the snow avalanche prone areas according to the number of persons.

Ticket sales points (entrances)	Share of ticket sales points in the average tourist traffic in the years 2010-2016 (%)	Tourist traffic according to the ticket sales points in the months I-IV and XI-XII in period 2012-2015 (persons)***	Snow avalanche prone areas
MKL (the lift)	29	128602	Kocioł Łomniczki
Szklarka	18	79822	-
Wodospad Kamieńczyk (only waterfall)	13	57649	-
Wang	11	48780	Kocioł Małego Stawu
Szrenica (the lift)	8	35476	Szrenicki Kocioł
Chojnik	7	31042	-
Kopa	6	26607	Biały Jar
Kamieńczyk Brama (entrance)*	5	22173	Szrenicki Kocioł
Orlinek**	3	13304	-
Total	**100**	**443455**	**-**

*Included also because the trail from the Kamieńczyk entrance to Szrenica is not closed in winter.

** Not included because a part of the trail from the Orlinek entrance to the Dom Śląski is closed in winter (from the Schronisko nad Łomniczką to the Dom Śląski).

*** In each case share (%) from this table was multiplied by 443455 (the sum for months I-IV and XI-XII from the Figure 2).

Source: study on the basis of [8, 21].

bicycles and cars from KRNAP data. The snow avalanche prone areas for which we determined the probability assigned the points of sale of admission tickets to KPN or the tourist research site that were closest to these areas.

We calculated for the examined snow avalanche areas the following risk indicators: the Obří důl (0.002515%), the Dlouhý důl (0.002260%), the Biały Jar (0.001702%), the Kocioł Małego Stawu (0.001560%), the Labský důl (0.001442%), the Wielki Śnieżny Kocioł (0.000832%), the Důl Bílého Labe (0.000481%), the Kotelní jamy (0.000445%), the Modrý důl (0.000431%), the

Kocioł Łomniczki (0.000147%), the Szrenicki Kocioł (0.000016%), the Kocioł Wielkiego Stawu (0.000012%) (Table 5).

DISCUSSION

The rescue of human life in the Western Sudetes, including the Giant Mountains, is the task of the GK GOPR which is one of 7 GOPR groups 11, 51, 14]. Its equivalent on the Czech side is the Horská služba ČR which functions in 7 districts, especially in the Giant Mountains [52]. The Director of the KPN is responsible for a security

Table 4. Tourist traffic in the Krkonošský národný park and the snow avalanche prone areas according to the number of persons.

Area	Traffic (persons)	Share (%)	Tourist traffic in the months I-IV and XI-XII in period 2012-2015 (persons)**	Snow avalanche prone area
Sněžka	149229	9.09	161425	-
Josefova bouda (by car)	145577	8.87	157474	-
Luční bouda modrá	139759	8.51	151181	-
Labská bouda	131567	8.01	142319	-
Jelenka	109827	6.69	118803	-
Nad Kovárnou	97712	5.95	105698	Obří důl
Výrovka Památník	92796	5.65	100380	Modrý důl
Výrovka Chalupa na Rozcestí	81717	4.98	88395	-
Mohyla Hanče a Vrbaty	69690	4.24	75385	-
Chalupa na Rozcestí	57246	3.49	61924	-
Labský důl	56405	3.44	61015	Labský důl
Pramen Labe	50327	3.07	54440	-
Růženčina zahrádka	48163	2.93	52099	Kotelní jamy
Tvarožník	45805	2.79	49548	Wielki Śnieżny Kocioł*
Luční bouda červená	42147	2.57	45592	Dlouhý důl
Martinova bouda modrá	41592	2.53	44991	-
Jantarová cesta	40755	2.48	44086	Kocioł Wielkiego Stawu*
Bílé Labe	35609	2.17	38519	Důl Bílého Labe
Martinova bouda zelená	30508	1.86	33001	-
Vosecká bouda	24199	1.47	26177	-
Krakonošova cesta	23609	1.44	25538	-

Area	Traffic (persons)	Share (%)	Tourist traffic in the months I-IV and XI-XII in period 2012-2015 (persons)**	Snow avalanche prone area
Černý Důl (by car)	22998	1.40	24878	-
Dolní Dvůr (by car)	19891	1.21	21517	-
Krakonošova snídaně	18571	1.13	20089	-
Výrovka Chalupa na Rozcestí (by bicycle)	12860	0.78	13911	-
Mohyla Hanče a Vrbaty (by bicycle)	11353	0.69	12281	-
Třídomí (by car)	10085	0.61	10909	-
Výrovka Památník (by bicycle)	9201	0.56	9953	-
Výrovka Památník (by car)	7822	0.48	8461	-
U Čtyř pánů (by bicycle)	6885	0.42	7448	-
Výrovka Chalupa na Rozcestí (by car)	4364	0.27	4721	-
Mohyla Hanče a Vrbaty (by car)	3688	0.22	3989	-
Total	**1641957**	**100.00**	**1776148**	**-**

* in these cases tourist traffic from areas in Czech part of the Giant Mountains was assigned to avalanche prone areas in Polish part of the Giant Mountains.

** in each case share (%) from this table was multiplied by 1776148 (the sum for months I-IV and XI-XII from the fig. 3)

Source: study on the basis of [22].

Table 5. The risk assessment in avalanche prone areas according to the risk indicator.

Area	1.	2.	3.	4.	5.	6.	7.	8.
Obří důl	12	18	25	43	64520	3.77359	0.000666	**0.002515**
Dlouhý důl	10	12	8	20	27830	3.14465	0.000719	**0.00226**
Biały Jar	4	22	14	36	26607	1.25786	0.001353	**0.001702**
Kocioł Małego Stawu	11	4	18	22	48780	3.45912	0.000451	**0.00156**
Labský důl	4	4	39	43	37245	1.25786	0.001155	**0.001452**
Wielki Śnieżny Kocioł	5	8	8	16	30246	1.57233	0.000529	**0.000832**
Důl Bílého Labe	4	1	8	9	23513	1.25786	0.000383	**0.000481**
Kotelní jamy	3	2	13	15	31803	0.9434	0.000472	**0.000445**
Modrý důl	7	6	6	12	61274	2.20126	0.000196	**0.000431**
Kocioł Łomniczki	5	5	7	12	128602	1.57233	0.000093	**0.000147**
Szrenicki Kocioł	1	2	1	3	57649	0.31447	0.000052	**0.000016**
Kocioł Wielkiego Stawu	1	0	1	1	26911	0.31447	0.000037	**0.000012**
Total	**67**	**84**	**148**	**232**	**564980**	**21.0692**	**0.000411**	**0.008652**

1. No. of snow avalanche events (in SAE's); **2.** Deaths; **3.** Affected; **4.** Total affected (**1** + **2**); **5.** No. of tourists; **6.** Probability (**1**/318 × 100%); **7.** Effects (**3**/**4**); **8.** Risk indicator (**6** × **7**)

Source: own study.

in the area of the Krkonošský národný park. Periodic regulations of accessibility (closures) or trails (winter trails or alternate trails) are introduced. In this scope, the KPN also cooperates with the GK GOPR [53]. In the area of the Krkonošský národný park, there are no such restrictions, however, on the trails crossing the avalanche tracks, the Horská služba ČR installs warning signs about the avalanche hazard prior to the beginning of winter [17, 54, 55, 18].

The greatest risk of a snow avalanche event occurred in the Obří důl (Figure 4) which is the most Snow avalanche prone area in the entire Giant Mountains and in their Czech part. On the Polish side, the most prone avalanche area remained the Biały Jar (Figure 5), which in the opinion of [11, 14], is a place especially endangered by avalanches.

The results of our research provide sufficient evidence to consider winter trips in the analyzed regions of the Giant Mountains as an example of an extreme form of physical activity (EFPA [58]). In this case (according to the classification of Kalina and Bąk [59]) the factor of the greatest risk is threat to health or life (C1). In the middle of the continuum of the scale of extremes, we rightly place the body burden with high level of effort (C3), and the closest to the "minimum" pole of this scale is the coordination difficulty (C2). In Poland, the tradition of extreme mountain tourism dates back to the nineteenth century and concerns the Tatra Mountains [60], i.e. the highest mountains in this part of Europe.

Therefore, all the results of reliable research on the quality of education of mountain rescue services [61] and specialists who undertake work in various types of physical activity – recreation, sport, physical education, kinesiotherapy, etc., are gaining significance [62-65]. This issue will become more and more important in the reality of the global COVID-19 pandemic [66, 67]. Therefore, the opinions of parents, caregivers and students on the effectiveness of education programs are important [68, 69].

However, the broadly understood prevention of threats to health or life during all EFPAs includes, among others, the subjective sense of all dimensions of health and survival ability of people of all ages, which should be verified by simple methods by high-class specialists [70-75].

In terms of not only educational, but also organizational, administrative and political issues, it is necessary to break the barriers blocking progress and the expected results in the area of public health [76-79]. On the other hand, research communities and creative practitioners should be open to innovative initiatives with high scientific and ethical standards [80-83, 66, 84].

CONCLUSIONS

The most dangerous places in the entire Giant Mountains are: the Obří důl, the Dlouhý důl, the Biały Jar and the Kocioł Małego Stawu. We falsified the hypothesis formulated at the beginning: 'The most prone avalanche area in the Giant Mountains is the Biały Jar'.

Placing in the third position and slightly ahead of the Kocioł Małego Stawu, the Biały Jar kept the name 'the most prone avalanche area in the Polish part of Giant Mountains'. The Kocioł Łomniczki, the Szrenicki Kocioł and the Kocioł Wielkiego Stawu were on the last three rank positions which means greater effectiveness of preventive activities conducted there by the KPN in cooperation with the GK GOPR in comparison with places such as the Biały Jar and the Kocioł Małego Stawu.

Activities undertaken by the KPN do not take the Správa KRNAP in Obři důl, Dlouhý důl and other avalanche prone areas on the Czech side. In ouropinion, the Správa KRNAP should do the same actions such as the KPN.

Moreover, the snow avalanche in the Biały Jar in the Giant Mountains in 1968 should be registered in the EM-DAT because it fulfils its criteria. The avalanches in this database should be registered with distinguishing types of snow and debris avalanches.

Next, in this article we failed to confirm that Biały Jar 'is one of the most avalanche and dangerous places in Polish mountains', as stated [10]. To verify this, further research is needed on the occurrence of snow avalanches in the Polish mountains and the tourist movement in the vicinity of snow avalanche prone areas.

Finally, we applied positively the new method – the snow avalanche event analysis (SAEA).

Figure 4. The Obří důl.
Source: picture by Zbigniew Piepiora.

Figure 5. The Biały Jar.
Source: picture by Zbigniew Piepiora.

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