Risk Factor Profile for Sudden Cardiac Death During Mountain Hiking

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Key words
- sudden cardiac death
- mountain hiking
- risk factors
- triggers

Abstract

Mountain hiking is associated with a death rate of about 4 deaths per 100 000 hikers annually. About 50% of all fatalities during mountain hiking are sudden cardiac deaths (SCDs). But there are only few data available regarding risk factors and triggers associated with SCD during mountain hiking. Thus, a case-control analysis between persons who died suddenly during mountain hiking and randomly selected controls was carried out. Risk factor profiles of 179 males over the age of 34 who suffered SCD during mountain hiking were compared to those of 537 matched controls. Hikers who died suddenly during mountain hiking were much more likely to have had a prior MI (17% vs. 0.9%; $p < 0.001$), known coronary artery disease (CAD) without prior MI (17% vs. 4%; $p < 0.001$), diabetes (6% vs. 1%; $p < 0.001$), hypercholesterolemia (54% vs. 20%; $p < 0.001$), and were less engaged in regular mountain sports activities (31% vs. 58%; $p < 0.001$) compared to hikers from the control group. Based on the reported relationship between traditional risk factors and coronary plaque morphology, acute plaque rupture with thrombus formation and subsequent lethal arrhythmias may be assumed to be a dominant mechanism precipitating SCD during hiking. In contrast, in skiers especially non-occlusive plaques may precipitate ischemia leading to an imbalance between oxygen demand and supply and subsequent lethal arrhythmias. As preventive measures recommended to hikers at risk, adaptation to regular mountain sports activities by an adequate training program and pharmacological interventions, e.g. lipid lowering drugs, aspirin, and beta-blockers, should be considered.

Introduction

Mountain hiking has become one of the most popular summer sports world-wide and especially in the Alps. Some million hikers visit Austria each year [5]. Mountain hiking is associated with a death rate of about 4 deaths per 100 000 hikers annually [6]. About 50% of all fatalities during mountain hiking are sudden cardiac deaths (SCDs) [6]. More than 90% of these fatalities occur in men over the age of 34. The risk of death clearly increases with age and is higher in hikers who are habitually sedentary [7], but there are no data available regarding additional risk factors and triggers associated with SCD during mountain hiking. Recently we demonstrated that downhill skiing has to be considered as a serious trigger for SCD especially in skiers with prior myocardial infarction (MI), but also for those with hypertension, known coronary artery disease (CAD) without prior MI or insufficient adaptation to strenuous exercise [4]. However, environmental conditions and the type of exercise are markedly different when downhill skiing is compared to hiking and thus, the stress on the cardiorespiratory system and probably risk factors and triggers for SCD may also differ. For the identification of high-risk individuals and the development of effective preventive measures, such information would be of great value. Therefore, a case-control analysis between persons who died suddenly during mountain hiking and randomly selected controls was carried out.

Methods

Cases

All deaths which occurred during mountain hiking during a nine year period in Austria were recorded by members of the Ministry of the Interior utilizing standardized forms [4,5]. Male hikers

accepted after revision
May 24, 2006

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DOI 10.1055/s-2007-964850
Published online 2007
Int J Sports Med © Georg Thieme Verlag KG Stuttgart · New York · ISSN 0172-4622

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> 34 years of age who suffered SCD during mountain hiking and who were residents of Austria or Germany were eligible for inclusion in the study. SCD was defined as unexpected, non-traumatic death in persons with or without pre-existing disease who died within 1 hour of the onset of symptoms [4,8]. Rare cases, in which cardiovascular processes such as intracerebral hemorrhage, pulmonary embolism and dissecting aortic aneurysm were demonstrated were excluded. Out of a total of 361 cases with SCD 301 fulfilled the inclusion criteria. Sixty cases were excluded because of a nationality other than Austrian or German or due to an age < 35 or female gender. For data collection on risk factor profiles addresses of spouses or close relatives of hikers who suffered sudden death were available in 229 cases. One hundred and seventy-nine questionnaires (78%) were returned and after subsequent telephone interviews for data completion, all of them were included for analyses.

Controls

Control subjects were recruited from the population of male hikers from Austria and Germany. Within 2 consecutive summer seasons 960 hikers were interviewed with a similar standardized questionnaire as used for cases. Inquiries were carried out on 40 frequented mountain paths and huts in the western part of the Austrian Alps. There, data from all male hikers over the age of 34 were recorded successively for a certain period in the morning and the afternoon. Less than 10% of hikers refused to answer the inquiry. Afterwards controls were matched to the cases in terms of age, nationality and frequency of mountain sports activities. Three controls were selected for each case.

Data collection

The questionnaire employed was tested in a preceding pilot study and was revised to improve clarity and facilitate statistical analysis. This questionnaire covered demographic variables, cardiovascular risk factors, medical history, physical activity, and additionally, symptoms and circumstances of sudden death for cases. Trained interviewers were responsible for the data collections. Habitual physical activity was classified as mild to moderate and strenuous activity. Mild to moderate activity was defined as needing up to 5 metabolic equivalents (METs; 1 MET = 3.5 ml/kg/min oxygen uptake) and strenuous activities of 6 or more METs [9]. A list of such activities was provided. We asked about the usual frequency of physical activities which the subjects participated in on a weekly basis with a minimum duration of 15 minutes.

Statistical analysis

Due to the study design the primary statistical approach was a case-control analysis between hikers who died suddenly during mountain hiking and randomly selected controls. Differences in cardiovascular risk factors, physical activity and demographic characteristics were evaluated univariately by Mann-Whitney, Chi-square or Fisher's exact tests. Logistic-regression analysis was used to estimate adjusted odds ratios and their 95% confidence intervals (CI) for cardiac death outcome. The final regression model included body mass index, prior MI, known CAD without prior MI, hypertension, hypercholesterolemia, diabetes, smoking, SCD in family history, and usual physical activities. All p-values were two-tailed and values below 0.05 were considered to indicate statistical significance.

Results

Males over the age of 34 who died suddenly during mountain hiking were much more likely to have had a prior MI, known CAD without prior MI, diabetes, hypercholesterolemia, and were engaged in less mountain sports activities compared with hikers from the control group. Seventeen percent of hikers who suffered SCD had a prior MI, 17% had known CAD without prior MI, 54% suffered from hypercholesterolemia and 6% from diabetes, and only 31% had performed mountain sports activities more than 2 weeks per year. The respective percentages reported in the control group were 0.9%, 4%, 20%, 1% and 58%.

Logistic regression analysis showed those 5 variables to be significantly predictive for SCD outcome during mountain hiking. Hikers with a previous MI had a 10.9 (CI: 3.8 – 30.9) times higher adjusted SCD risk, those with diabetes a 7.4 (1.6 – 34.3), those with known CAD without prior MI a 4.7 (2.4 – 9.2), and hikers with hypercholesterolemia a 3.4 (2.2 – 5.2) fold increased risk. Mountain sports activities for more than 2 weeks per year effected a marked risk reduction 0.23 (0.1 – 0.4).

Discussion

Prior MI, diabetes mellitus, known CAD without prior MI, and hypercholesterolemia were found to be independent risk factors associated with SCD during mountain hiking in males over the age of 34. Regular mountain sports activities decreased the SCD risk. The epidemiological association between these factors and the risk of all manifestations of coronary artery disease including SCD is well established [8,17]. Population based studies have shown an annual SCD rate of 2.6/1000 men over the age of 34 [8]. Recently we found this risk to be increased by a factor 4.3 during mountain hiking [7]. Moreover no increase was found for men participating regularly in mountain sports activities. That observation is confirmed by the actual study.

The major risk factor for SCD during mountain hiking is prior MI enhancing the SCD rate about 11 fold. However, this increased risk is similar as shown for the high-risk group of men > 34 yrs with prior MI out of the normal population [13]. In contrast, hypercholesterolemia, diabetes, and physical inactivity are associated with a higher SCD-risk in hikers compared to the overall group of middle-aged men [17].

Whereas these risk factors point to metabolic aspects, the most important risk factors (hypertension, prior MI) in downhill skiers [4] rather indicate mechanical aspects of the risk origin. Although the risk factor profiles are similar in the controls of hikers and skiers they clearly differ between hikers and skiers who suffered SCD (**Fig. 1**).

This difference may well arise from the different types of exercise and/or environmental conditions. Whereas downhill skiing is characterized by intermittent bouts of intensive static-dynamic short term (1 – 3 minutes) work loads mountain hiking means prolonged relatively uniform exertion at an intensity below the individual anaerobic threshold [5]. Downhill skiing is usually performed in the winter time at low ambient temperature with relatively rapid changes in altitude and mountain hiking is performed in the summer months at comparatively warm temperature with rather slow ascents and descents. We are not able to differentiate the risk contribution arising from the alpine climate or the type of exercise, but certain combinations of both may represent discriminative triggers for SCD.

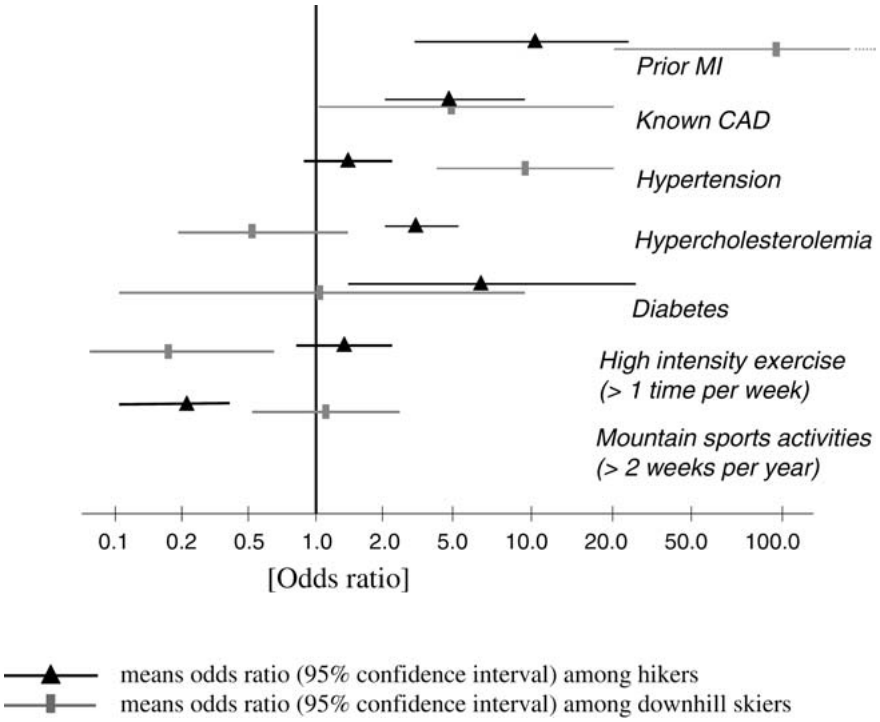

Fig. 1 Adjusted odds ratios (95% confidence intervals) regarding the prevalence of risk factors among mountain hikers and downhill skiers who suffered SCD compared to controls (hikers or skiers without SCD).

Table 1 Characteristics and odds ratios regarding the prevalence of risk factors among hikers who suffered sudden cardiac death as compared with controls

	Hikers with sudden death (n = 179)	Controls (n = 537)	Odds ratio (95%CI) univariate	p-value	Odds ratio (95%CI) multivariate	p-value
Age, yrs	60.6(± 9.0)	59.4(± 8.2)				
Height, cm	175.0(± 6.3)	176.9(± 18.5)				
Weight, kg	79.1(± 10.6)	76.3(± 8.4)				
Body mass index, kg/m^2, > 25 (%)	104 (58)	208 (39)	2.2 (1.6 – 3.1)	0.001	1.2 (0.8 – 1.8)	0.4
Prior MI, yes (%)	31 (17)	5 (0.9)	22.3 (8.5 – 58.3)	< 0.001	10.9 (3.8 – 30.9)	< 0.001
Known CAD without prior MI, yes (%)	30 (17)	23 (4)	4.5 (2.5 – 8.0)	< 0.001	4.7 (2.4 – 9.2)	< 0.001
Hypertension, yes (%)	73 (41)	97 (18)	3.1 (2.2 – 4.5)	< 0.001	1.5 (0.9 – 2.4)	0.1
Hypercholesterolemia, yes (%)	96 (54)	109 (20)	4.5 (3.2 – 6.5)	< 0.001	3.4 (2.2 – 5.2)	< 0.001
Diabetes, yes (%)	11 (6)	3 (1)	11.7 (3.2 – 42.3)	< 0.001	7.4 (1.6 – 34.3)	< 0.001
Smoking, yes (%)	44 (25)	133 (25)	1.0 (0.7 – 1.5)	1.0	0.64 (0.4 – 1.1)	0.08
SCD in family history, yes, (%)	52 (29)	103 (19)	1.7 (1.2 – 2.5)	< 0.01	1.0 (0.6 – 1.7)	0.9
Light to moderate physical activities > 3 times per week, (%)	101 (56)	389 (72)	0.49 (0.4 – 0.7)	< 0.01	0.9 (0.6 – 1.4)	0.64
High intensity exercise > 1 time per week, (%)	35 (20)	112 (21)	0.92 (0.6 – 1.4)	0.7	1.4 (0.8 – 2.3)	0.22
Mountain sports activities > 2 weeks per year, (%)	55 (31)	311 (58)	0.32 (0.2 – 0.5)	< 0.001	0.23 (0.1 – 0.4)	< 0.001

Data are presented as means (± SD), frequencies (percentages). Univariate analyses were conducted using the Chi-square or Fisher's exact test. Adjusted odds ratios (and 95% confidence intervals, CI) were derived by conditional logistic-regression analysis

Coronary artery sclerosis is the overwhelming cause of SCD in persons > 34 yrs and traditional risk factors have been shown to be correlated to coronary plaque morphology. Healed MI and systemic hypertension were rather related to SCD with stable plaques and hypercholesterolemia with acute plaque rupture [16]. Because of the differences in the risk factor profiles seen between skiers and hikers (**Fig. 1**), it is suspected that different pathophysiological mechanisms are responsible for SCD in skiers and hikers. Therefore in skiers especially non-occlusive plaques may precipitate ischemia leading to an imbalance between oxygen demand and supply and subsequent lethal arrhythmias. In contrast acute plaque rupture with thrombus formation and subsequent lethal arrhythmias may be assumed to be a more dominant mechanism precipitating SCD during hiking. Prolonged exercise favors electrolyte abnormalities, increase in free fatty acid concentration, and body temperature, all known to favor ventricular arrhythmias [11]. Thus, acute plaque rupture may rather lead to SCD in the state of high susceptibility for ventricular arrhythmias.

In downhill skiers with prior MI we have demonstrated that the rapidly increasing heart rate and rate pressure product during skiing at moderate altitude easily provokes ST-abnormalities

and angina which in some cases could provoke ischemia-related arrhythmias and SCD [3]. Both, blood pressure and the death risk from CAD have been shown to be higher during the cold winter months [15]. It is also known from *in vivo* phosphor-31 magnetic resonance spectroscopy studies of the myocardium that patients with CAD have a lower ratio of phosphocreatine (PCr) to ATP compared to age-matched healthy controls, whereby CAD patients showed a larger decrease in the myocardial PCr to ATP ratio during exercise than controls [18]. The PCr concentration in the muscle cell reflects the capacity of the oxidative metabolism and mitochondrial function [14]. Thus, changes in the energetic state of the myocardium could well contribute to an explanation for the increased SCD risk in skiers and hikers with CAD. In isolated rat hearts made hypoxic, the extent of myocardial PCr depletion was predictive of the occurrence of ventricular fibrillation [10].

However, hikers more adapted to regular mountain sports activities have some protection against SCD. There is good evidence from epidemiological and interventional studies that regular exercise prevents SCD [1,2]. The fact that skiers can take advantage from regular intense exercise and hikers from regular mountaineering points also to the importance of the specific type of exercise for SCD prevention during the various sports activities. Beside regular physical activity, measures for SCD prevention in hikers have to focus on the detection and the adequate treatment of risk factors, e.g. hypercholesterolemia and diabetes, and on effective pharmacological interventions in post MI patients, e.g. aspirin and beta-blockers [12].

Although the case control design appears to be the only feasible approach to study risk factors for sudden cardiac death in this setting, there are clearly known limitations of this study design mainly regarding the assessment of exposure (i.e. risk factors) and the selection of controls. We tried to minimize a possible recall bias through the use of a pre-tested standardized questionnaire applied by trained interviewers. In order to reduce the risk for selection bias we applied a series of strict inclusion/exclusion as well as matching criteria.

In conclusion, male hikers over the age of 34 who died suddenly during mountain hiking much more frequently had prior MI, diabetes, hypercholesterolemia or known CAD without prior MI, and were less engaged in regular mountain sports activities as compared to hikers of the control group. Therefore, adaptation to regular mountain sports activities and therapeutic interventions or abstinence from hiking in certain cases should be considered for mountain hikers at high risk.

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