HYPOXIA AND THE CIRCULATION

Edited by
Robert C. Roach
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and
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PREFACE AND ACKNOWLEDGEMENTS

The International Hypoxia Symposia convenes every other year to bring together international experts from many fields to explore the state of the art in normal and pathophysiological responses to hypoxia. Representatives from 22 countries joined together in February 2007 for four days of intense scientific discourse in the dramatic mountain setting of Lake Louise, Canada.

The 15th International Hypoxia Symposium was a rewarding experience due to the outstanding faculty and the lively participation of our largest-ever group of participants. At this, our fifth meeting as the organizers, we were especially pleased that the Hypoxia Meetings continue to prosper. We remain always thankful for the kind and wise guidance of Charlie Houston, the originator of the Hypoxia meetings.

We strive to maintain a 30-year tradition of presenting a stimulating blend of clinical and basic science papers focused on hypoxia. Topics for 2007 included the risk of heart disease at high altitude, and the regulation of stroke volume and coronary blood flow. Also covered were metabolic, cognitive and vascular consequences of intermittent hypoxia, vascular remodeling in different vascular beds, lung fluid movement in hypoxia, new work on globins, including neuroglobin, myoglobin and genetic regulation of hemoglobin mass. Hypoxic responses in insects and the hypoxic skeletal muscle rounded out the regular sessions. We also had tributes to the 2007 Hypoxia Honoree, Professor James Milledge, and a special tribute to our late friend, Dr. Carlos “Choclo” Monge Cassinelli.

The abstracts from the 2007 meeting were published in High Altitude Medicine & Biology Dec 2006, Vol. 7, No. 4: 319-350. Late abstracts are presented in the last chapter of this volume.

We hope that this collection of papers especially prepared for this volume allows us to share with a broader audience some of the intellectual excitement that embodies the spirit of the Hypoxia meetings.

In 2007 we had the generous support of a number of organizations and individuals, including the U.S. Army Research and Development Command, The White Mountain Research Station, the John Sutton Fund from McMaster University, and our International Advisory Committee. At the meeting we were greatly helped by Barbara Lommen, Paige Sheen, Kelly Brown, Gene and Rosann McCullough and Andy Subudhi who each made a tremendous effort to make every delegate feel at home, and to make the meeting go very smoothly.

Please join us by the light of the full moon in February 2009 at the Chateau Lake Louise, Lake Louise, Alberta, Canada for the 16th International Hypoxia Symposium.

(www.hypoxia.net)
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Chapter 1

RISK OF CARDIOVASCULAR EVENTS DURING MOUNTAIN ACTIVITIES

Martin Burtscher
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Abstract: Sudden cardiac death (SCD) is the major cause of fatalities in males over 34 years of age during hiking or downhill skiing in the mountains. The main goal of the present study was the identification of risk factors and triggers associated with SCDs during these mountain activities. Besides recording individual circumstances associated with SCD, a case-control study was performed comparing the risk factor profiles of 247 males over the age of 34 who suffered SCD during mountain hiking or downhill skiing with those of 741 matched controls. The SCD risk was greatest on the first day at altitude but altitude per se and the duration of activity did not appear to markedly modify this risk. In contrast, the longer the time from the last food and fluid intake during hiking, the higher was the SCD risk. Early cardio-pulmonary resuscitation was started in 33 % of skiers and in 14 % of hikers after occurrence of unconsciousness. Hikers who died suddenly during mountain hiking were much more likely to have had a prior myocardial infarction (MI) (17 % vs. 0.9 %), known coronary artery disease (CAD) without prior MI (17 % vs. 4 %), diabetes (6 % vs. 1 %), hypercholesterolemia (54 % vs. 20 %), and were also less engaged in regular mountaineering activities (31 % vs. 58 %) compared with hikers from the control group (all P < 0.001). Skiers who suffered SCD had much more frequently a prior MI (41 % vs. 1.5 %), hypertension (50 % vs. 17 %), known CAD without prior MI (9 % vs. 3 %), and were less engaged in regular strenuous exercise (4 % vs. 15 %) when compared to controls (all P < 0.05). These findings enable identification of skiers and hikers at increased SCD-risk and recommendation of preventive measures, e.g. pharmacological interventions and adaptation to specific mountain activities. They also underline the need for intensified cardio-pulmonary resuscitation training for all mountaineers.

Key Words: sudden cardiac death, downhill skiing, mountain hiking, exercise, regular physical activity

INTRODUCTION

The Alps comprise the largest and most popular sports region in Europe. Austria accounts for almost one third of the 180,000 km² of mountainous area. In Austria alone, each year more than 10 million persons from practically every country in the world are

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involved in one of the many mountain activities (downhill skiing, mountain hiking, ski-touring, rock climbing, ice-climbing, snow boarding, mountain biking, paragliding, etc.). About 85 percent of these people are downhill skiers and/or mountain hikers (4). Whereas mountain sports activities can undoubtedly contribute to fitness and longevity, they are also combined with a relatively high risk of death (2, 6). In Austria there are about 300 fatalities during mountain sports annually. About 30 % of these deaths are non-traumatic deaths, mostly sudden cardiac deaths (SCDs) (4). Based on accumulating reports on fatal cardiac events in hikers and skiers during the peak vacation periods, the impression arises that downhill skiing, like mountain hiking in summer, is associated with a particularly high risk of SCD. Numerous studies have estimated the frequency of SCDs to the general public and during vigorous exercise (10, 15, 24, 25, 29, 35). However, relatively little data are available on SCDs which occur during hiking or downhill skiing (7, 8).

For this reason, the main objectives of the present paper are the estimation of the SCD-risk during downhill skiing and mountain hiking and the identification of main risk groups and risk factors associated with SCD.

METHODS

The recording of fatalities during mountain sports activities in Austria, the estimation of the respective population at risk, and the case-control analyses for the determination of risk factors have recently been described elsewhere (3, 4) and will only be presented here briefly.

Fatalities during mountain sports activities and diagnosis of deaths

All fatalities during mountain sports activities in Austria within a nine year period were recorded by qualified alpinists with para-medical training. Data encompassed characteristics of the mountaineers (age, sex, nationality, the type of mountain sport practiced, etc.), the circumstances of the fatality, the doctor’s diagnosis and further details like terrain, altitude, and weather conditions. The diagnosis of “sudden cardiac death” has been made by the emergency physician, by the doctor in the hospital and sometimes additionally on the basis of the results of an autopsy which was performed in about 10% of all cases.

Sudden cardiac death is defined as unexpected, non-traumatic death in persons with or without pre-existing disease who die within 1 hour of the onset of symptoms with exclusion of CVA and PE (9, 20).

The population at risk

The total number of hikers and skiers is based on a representative Austrian-wide survey which has been carried out to determine the number of persons involved in individual mountain sports activities, differentiation according to age and sex, and the frequency of involvement in (alpine) sports (26), on data collected among a representa-
tive sample of hikers and skiers in Austria (13), and on microcensus (1, 16).

**The case-control-study**

**Cases:** All deaths which occurred during mountain hiking and downhill skiing during a nine year period in Austria were recorded. Males > 34 years of age who suffered SCD during mountain hiking or downhill skiing and who were residents of Austria or Germany were eligible for inclusion in the study. Rare cases in which cardiovascular processes such as intracerebral hemorrhage, pulmonary embolism and dissecting aortic aneurysm were demonstrated were excluded. Out of all recorded cases (n = 518) with SCD 405 fulfilled the inclusion criteria. For data collection on risk factor profiles, addresses of spouses or close relatives of hikers and skiers who suffered sudden death were available in 314 cases. 247 questionnaires (79 %) 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 and skiers from Austria and Germany. Within 2 consecutive summer and winter seasons, hikers and skiers were interviewed with a similar standardised questionnaire as used for cases. Inquiries were carried out on 40 frequented mountain paths and huts and in 3 Austrian ski resorts of the western part of the Austrian Alps. There, data from all male hikers and skiers over the age of 34 were recorded successively for a certain period in the morning and the afternoon. Less than 10 % refused the inquiry. Afterwards, controls were matched to the cases in terms of age, nationality, type and frequency of mountain sports activities. Three controls (n = 741) 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, individual conditions at the day of death like nutrition, start of the sports activity, etc., and symptoms and circumstances of sudden death and information on resuscitation 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 (35).

**Statistics**

Data are mainly presented as frequencies. Due to the study design the primary statistical approach was a case-control analysis between hikers who died suddenly during mountain hiking or downhill skiing 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 for cardiac death outcome. All P values were two-tailed and values below 0.05 were considered to indicate statistical significance.
RESULTS

Frequency of SCDs during a 9 year observation period

The age and gender-related numbers of SCDs during mountain hiking and downhill skiing within a 9 year period in Austria are shown in Table 1. Male hikers and skiers over the age of 40 comprise about 90 percent of all SCDs. SCDs are rare in females and young males. However, young females seem to have relatively frequent SCDs during skiing as compared with females over 40 years of age. Considering the age distribution of the male population at risk, a steep increase of the SCD risk with increasing age becomes obvious (Fig.1).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Hikers</th>
<th>Skiers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>&lt; 20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>21-40</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>41-60</td>
<td>166</td>
<td>12</td>
</tr>
<tr>
<td>&gt; 60</td>
<td>192</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>372</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 1. Age- and gender-dependent numbers of sudden cardiac deaths (SCDs) during hiking and skiing in the Austrian Alps within a 9 year observation period

Figure 1. Age-specific proportions of SCDs in male mountain hikers and downhill skiers over the age of 34.