

ORIGINAL RESEARCH

Variables Contributing to Acute Mountain Sickness on the Summit of Mt Whitney

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Objective.—The interaction of 15 variables representing physical characteristics, previous altitude exposure, and ascent data was analyzed to determine their contribution to acute mountain sickness (AMS).

Methods.—Questionnaires were obtained from 359 volunteers upon reaching the summit of Mt Whitney (4419 m). Heart rate and arterial oxygen saturation were measured with a pulse oximeter, and AMS was identified by Lake Louise Self-Assessment scoring. Multiple logistic regression analysis was used to identify significant protective and risk factors for AMS.

Results.—Thirty-three percent of the sample met the criteria for AMS. The odds of experiencing AMS were greater for those who reported a previous altitude illness (adjusted odds ratio [OR] = 2.00, $P < .01$) or who were taking analgesics during the ascent (adjusted OR = 2.09, $P < .01$). Odds for AMS decreased with increasing age (adjusted OR = 0.82, $P < .0001$), a greater number of climbs above 3000 m in the past month (adjusted OR = 0.92, $P < .05$), and use of acetazolamide during the ascent (adjusted OR = 0.33, $P < .05$).

Conclusions.—The significant determinants of AMS on the summit of Mt Whitney were age, a history of altitude illness, number of climbs above 3000 m in the past month, and use of acetazolamide and analgesics during ascent.

Key words: altitude illness, hypoxia, arterial oxygen saturation, trekking, mountaineering

Introduction

Trekkers and mountaineers are often concerned with developing acute mountain sickness (AMS) during their ascents. Acute mountain sickness has been defined as a self-limiting syndrome that commonly occurs in unacclimatized individuals who ascend too rapidly to altitudes higher than 2500 m.¹ The syndrome is characterized by a headache accompanied with other symptoms that may include gastrointestinal distress (eg, nausea, vomiting, and loss of appetite), fatigue or lassitude, dizziness, and sleep disturbances. Hydration, drug treat-

ment, and descent are advised depending on the severity of symptoms. Resolution of AMS typically occurs after a couple days of acclimatization to the new altitude or upon descent to a lower altitude. However, if symptoms are ignored, and ascent continues, AMS can develop into life-threatening high-altitude cerebral edema. The pathophysiology of AMS has been reviewed,^{2,3} and several researchers have investigated the interaction of risk factors in an attempt to determine what contributes to this syndrome.^{4–8}

Mt Whitney (4419 m) is the highest point in the contiguous 48 states of the United States. There are numerous routes of varying difficulty to reach the summit, with no technical climbing or mountaineering skill required for an ascent of the easiest route. The trailhead (2550 m) can be accessed by a paved road. Because of its distinction of being the “highest” summit, being easy to access, and having a nontechnical climbing route, Mt

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Whitney sees many attempts by both novice and experienced mountaineers alike, thereby providing an ideal setting to study AMS. Furthermore, the mountain is located within a half-day drive of many highly populated California coastal cities. Thus, many of the attempts are made by unacclimatized residents who live at sea level.

The aim of our study was to expand upon previous AMS investigations by examining the interactions of numerous variables that might contribute to this syndrome on the summit of Mt Whitney. In addition to analyzing more self-report variables than have previous studies, we also included measurable variables of interest such as heart rate and arterial oxygen saturation (%SaO₂) as well as the influence of medication. Additionally, most mountaineering studies involve a rather homogeneous population. The uniqueness of Mt Whitney provided a sample that had more female participants and greater variability regarding age, body mass index (BMI), time spent training, and previous experience at high altitudes than what is seen in most mountaineering studies. Finally, this study is unique in that it was delimited to summiteers rather than all climbers. Climbers often ignore symptoms and reach summits despite being in an unhealthy state, and we wanted to determine the prevalence of AMS on one of the most sought-after summits in the United States. Thus, the inclusion of many variables, the diversity of our sample, and the focus on summiteers created a unique study to identify variables that might significantly contribute to AMS, thereby adding to the knowledge of this syndrome.

Methods

SETTING AND SUBJECTS

Data collection took place on the summit of Mt Whitney (4419 m) during 5 consecutive days in August 2004. People who reached the summit during this time were invited to participate in this study. After explaining the purpose, objectives, and procedures of the study, informed consent for participation was obtained. Subjects had the opportunity and were encouraged to ask questions about the study, and participation was entirely voluntary. Although a tally of those declining to participate was not kept, the participation rate was extremely high, with nearly all summiteers volunteering for the data collection. The study was approved by the participating institutions and granting agencies, and a special-use permit was granted for this data collection by the Inyo National Forest Service.

People who ascend this mountain from the west are often on treks of long duration and are well acclimatized to high altitude. In contrast, ascents from the east side

of the mountain are typically done in 1 to 3 days. Only data from summiteers who ascended from the east side of the mountain (Whitney Portal) were included in the analyses ($n = 359$). This was the only exclusion criterion.

QUESTIONNAIRE AND PULSE OXIMETRY

Information about the subjects' physical characteristics, acclimatization, experience at high altitudes, and ascent was obtained from a questionnaire. Personal data included age, gender, smoking status, and height and weight for subsequent calculation of BMI. In an effort to quantify previous altitude exposure and acclimatization history, subjects were asked about their altitude of residence, the number of times that they had been above 3000 m in the month before this ascent, the approximate number of times they had been above 3000 m in their lifetime, the highest altitude that they had ever hiked to before this ascent, and whether they had ever experienced altitude sickness. The variable of hours per week of training in the month before the ascent was used to quantify physical conditioning. Ascent data included the day and time that the subjects started their ascent (from the Whitney Portal trailhead) and reached the summit for subsequent calculation of ascent time, an estimate of the amount of liquid consumed, and any medications that were taken during this time.

In addition to self-report data obtained from the questionnaire, heart rate and %SaO₂ were measured with a finger pulse oximeter (SportStat, Nonin Medical Inc, Plymouth, MN). Pulse oximetry data collection occurred 5 to 10 minutes after the subjects reached the summit. The right index finger was used for this measurement.

ASSESSMENT OF AMS

Acute mountain sickness was assessed by the Lake Louise Self-Assessment score.¹ This commonly used assessment includes 5 symptoms: headache, gastrointestinal distress, fatigue or weakness (or both), dizziness or lightheadedness, and difficulty sleeping. Each symptom is scored 0 (not present) through 3 (severe or incapacitating) for a combined minimal score of 0 and a maximal score of 15. Our criteria for AMS were 1) a headache, 2) at least 1 other symptom, and 3) a total score of 3 or more. This constitutes the preferred assessment method and criteria for evaluating AMS.⁹

STATISTICAL ANALYSIS

Basic descriptive statistics, including measures of central tendency, variance, and frequency, were computed for

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