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ORIGINAL RESEARCH

Smoking Increases the Risk of Acute Mountain Sickness

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Objective.—We aimed to ascertain risk factors for acute mountain sickness (AMS) in miners exposed to chronic intermittent high altitude conditions.

Methods.—All new hires (2009–2012) for mine employment (4000 m above sea level) were followed up for 12 months after first ascent. Demographics, physiologic data, and cigarette smoking were assessed at preemployment screening. Mine site clinic care for AMS defined incident events. Cox regression analysis estimated risk of AMS associated with smoking and selected covariates.

Results.—There were 46 AMS cases among 569 individuals during the first 12 months of employment. Adjusted for age, sex, and altitude of permanent residence, cigarettes smoked per day before hiring were prospectively associated with AMS (hazard ratio [HR], 1.9; 95% CI, 1.1 to 3.2 per 10 cigarettes smoked). This risk was higher in the subset of workers with less demanding physical work (n = 336; HR, 3.3; 95% CI, 1.7 to 6.3), whereas among those with more physically demanding jobs (n = 233), smoking was not associated with increased risk (HR, 0.6; 95% CI, 0.1 to 2.3).

Conclusions.—In workers newly hired to work at high altitude, smoking increases the likelihood of AMS, but this effect appears to be operative only among those with less physically demanding work duties.

Key words: smoking, high altitude, acute mountain sickness, mining, occupational

Introduction

Acute mountain sickness (AMS) is common, typically occurring among persons ascending to an altitude of at least 2500 m above sea level (MASL). Manifestations of AMS include headache (which can be incapacitating) and other neurological and cardiovascular signs and symptoms.[1] Although presenting over a range of severity, AMS potentially can progress to life-threatening complications, including high altitude pulmonary edema and high altitude cerebral edema.[2,3]

Precisely because of these potentially severe complications, identifying the risk factors for AMS is important. Altitude, a well-established risk factor for AMS, is not amenable to modification. Other factors include a previous AMS event, rapidity of ascent, and lack of acclimatization.[1,4] Among other potential risk factors, cigarette smoking is particularly important because it is modifiable. Previous findings in regard to smoking and AMS, however, have been quite variable, making this a confusing topic.[4–17]

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Relative to alpinists and trekkers, workers exposed to high altitude are an important but understudied risk group for AMS and its complications. Because working in on-site/off-site shifts at altitude does not allow for full acclimatization, AMS is likely to occur even after repeated ascents, leading to a cumulative elevated incidence of morbidity. Examining intermittently exposed subjects presents an important opportunity to study AMS in such a high-risk group, especially during the initial months of employment. In an earlier case-referent study of employees of a mining company working at an altitude of 4000 MASL, we observed that smoking was associated with increased odds of severe AMS (symptoms leading to compression chamber treatment).[8] We wished to build on those findings by studying a nonoverlapping cohort from the same worksite, analyzing prospective risk factors for AMS, especially smoking, during the first year of employment.

Materials and Methods

In this cohort analysis of newly hired employees at a high altitude mining operation, we assessed the risk of AMS during the first 12 months of employment. The

mine is located in the Tien Shan Mountains of Kyrgyzstan, with work sites at 3800 to 4500 MASL. Mining personnel commute on buses (journey of $\leq$8 hours) from residences either in the Issykul Lake plateau (1600 MASL) or in Bishkek and its environs (700 MASL) for 2-week on-site rotations (2 weeks on and 2 weeks off mine site).

All company employees undergo preplacement examinations. These include evaluations by 8 medical specialists or subspecialists along with relevant laboratory and ancillary testing. An electronic medical database includes these data as well as an oxygen saturation performed within the first hour of arrival at the mine site. The database also tracks any unscheduled walk-in visits to the mine site clinic, including mandatory entry of an associated diagnostic code. This includes 2 possible codes for symptoms consistent with altitude-related illness: "mountain sickness" and "acute mountain sickness." Although distinct options, in practice they are applied interchangeably and thus were collapsed into a single diagnostic entity of AMS for the purposes of this analysis. Typical symptoms that trigger the diagnosis of AMS being assigned are persistent headache (especially with a poor response to acetaminophen or ibuprofen), dizziness, shortness of breath, gastrointestinal complaints, sleep disturbance, and fatigue. In practice, systematic standard elicitation of complaints yielding a Lake Louise Score (LLS)—a diagnostic, symptom-based severity system for AMS[18]—was only initiated at the mine site after the period of this study. All workers have equal access to the on-site medical clinical while at the mine. Neither acetazolamide nor dexamethasone is used as a primary prevention among newly hired employees before a first AMS episode.

We constructed the study cohort by considering as potentially eligible all newly hired regular employees (trainee interns were not eligible) with preemployment screening obtained during the 4-year period between January 1, 2009 and December 31, 2012. Persons who were examined but not hired, including those who did not pass preemployment screening, were ineligible for cohort entry. We excluded otherwise eligible subjects who were employed to work at company locations other than the high altitude mine site and those who had no AMS event but did not complete 12 months of initial employment. Ultimately, 134 otherwise eligible subjects were excluded. There was no overlap between members of this cohort and the study population that we previously investigated in our earlier study of more severe AMS.[8]

Baseline preemployment screening data were used to derive demographics, place of permanent residence, and physical examination and testing data. The choice of independent predictor variables of interest was informed by our previous analysis of more severe AMS as well as risks identified in other studies on AMS. Screening data included height and weight (yielding body mass index [BMI]), blood pressure, heart rate, hemoglobin, and pulmonary function testing (yielding forced expiratory volume in 1 second [FEV_1] and forced vital capacity [FVC];) (MicroLoop portable spirometer; CareFusion, Basingstoke, Hampshire, United Kingdom, performed to Kyrgyzstan guidelines).[19] Oxygen saturation (Sao_2) obtained later at the mine site at first ascent was measured with standard equipment (ProPaq Encore monitor; Welch Allyn, Skaneateles Falls, NY).

We dichotomized new hires' occupations into those with less and more physically demanding job duties based on well-established job descriptions. The lower-demand jobs included all office staff (eg, engineers, interpreters, safety people, first aid and other clinical staffs, geologists, and secretaries); as well as security personnel, electricians, and all categories of drivers of heavy machinery (eg, haul truck drivers, passenger vehicles, and buses). We classified as high-demand jobs mechanics, drilling machine operators and related personnel; cleaners, mill operators, kitchen staff, warehousemen, blasters, underground operators, and riggers.

The cigarette smoking status of each mine employee at the time of preemployment was quantified in terms of self-reported current daily smoking (yes or no) and, for current smokers, smoking intensity in cigarettes smoked per day. Reported smoking intensity reflected that as recorded on a day of baseline examination. Data were not available on interval changes in smoking status intensity that may have occurred during follow-up. In addition, all those examined, regardless of smoking status, were further assessed with an exhaled carbon monoxide (CO) measurement using a portable breath CO analyzer (Smokerlyzer; Bedfont, Maidstone, Kent, United Kingdom). Based on the timing of examinations, the CO measurement is conducted at least 2 hours after the last cigarette smoked. We did not assess occupational secondhand tobacco smoke because company policy has banned smoking in all dormitories, common areas, and work sites. Dormitory heating and cooking is centralized without general exposure to combustion byproducts (eg, biomass fuels or individual cooking stoves).

Each employee was considered at risk for AMS for the entire first year of employment (365 days). During that period, we interrogated the medical database to identify any mine site visit coded for AMS, extracting the number of days elapsed after the first ascent to the mine until the first AMS event was recorded. Censoring observations at first AMS event or at the end of the first 365 days of employment (that is, considering subjects at