Prevalence of sleep-disordered breathing in truck drivers at a mine located at high altitude

Jorge Rey de Castro, Oswaldo Ortiz, Edmund Rosales-Mayor, Jenny Ferreyra, Alicia Liendo, César Herman Liendo

ABSTRACT

Objectives: To determine the prevalence of sleep-disordered breathing in Peruvian truck drivers working at high altitudes and to validate the automatic versus manual scoring system of a respiratory polygraph test. Methods: A cross-sectional and probabilistic study was conducted on truck drivers working the day shift at 2,020 meters above sea level. The collected information included anthropometric variables, the Epworth Sleepiness Scale (ESS), and the Lake Louise Acute Mountain Sickness (AMS) Questionnaire. A simplified type III screening instrument was used, and each recording was scored both automatically and manually. Results: In a total population of 70 drivers, 63 respiratory polygraph tests were conducted and four recordings were excluded. Out of the final sample of 59 (84%) drivers, 46 (78%) were normal, seven (12%) had altitude-induced central sleep apnea, and six (10%) showed obstructive sleep apnea-hypopnea syndrome. The results from the ESS and the Lake Louise AMS Questionnaire were normal for all three groups. Six out of seven drivers with central sleep apnea were intermittently exposed to altitude. No demographic variable was able to predict the abnormal test results. The automatic and manual methods for scoring respiratory events were similar according to the Pearson correlation and the Bland-Altman analysis, $r = 0.992$ for the apnea-hypopnea index ($p < 0.001$) and $r = 0.945$ for the central sleep apnea index ($p < 0.001$). Conclusion: A high prevalence of sleep-disordered breathing was observed, and no predictive variables for an abnormal study were identified. The use of simplified instruments is recommended to identify sleep-disordered breathing in drivers working at high altitudes who are far away from specialized sleep laboratories.

Keywords: altitude, automobile driving, sleep-disordered breathing.

INTRODUCTION

Sleep-disordered breathing (SDB), especially sleep apnea-hypopnea syndrome (SAHS), has a high prevalence in the general population, irrespective of gender. The prevalence of this epidemiologic variable fluctuates between 3-6% for symptomatic SAHS and 24-26% for asymptomatic SAHS. SAHS causes drowsiness, poor sleep quality, poor quality of life, neurocognitive deficits, and cardiorespiratory complications. The prevalence of SAHS is higher in drivers than in the general population, fluctuating between 17%-28%. SAHS-associated risks include arterial hypertension, coronary heart disease, cerebrovascular...
events, traffic accidents due to driver drowsiness, and death due to heart attack or stroke. \(^{(10)}\)

Periodic breathing (PB) is a well-recognized phenomenon in healthy subjects exposed to high altitude. It has a higher incidence in miners ascending to camps compared to high altitude natives. \(^{(11,12)}\) Furthermore, the worsening of SAHS has been reported as a consequence of the increase in central events when SAHS-stricken individuals are exposed to high altitudes. \(^{(13)}\)

The prevalence of motor vehicle accidents linked to drivers with SDB has been described at other altitudes as fluctuating between 20%-50% \(^{(14-17)}\). In Peru, the prevalence of SAHS in drivers working at high altitudes is not known. However, the association between sleepiness and traffic accidents has been documented in field studies utilizing questionnaires. This information suggests that passenger-bus drivers on highways work under drowsy conditions, have inadequate systematic periods of rest and disordered rotations, drive almost exclusively during the night shift, and suffer acute and chronic sleep deprivation. \(^{(18)}\)

The objective of our study was to determine the prevalence of obstructive and central SDB in drivers working in a mining area at 2,020 meters above sea level (m.a.s.l) and to validate an automatic scoring system for a respiratory polygraph compared to a manual system.

**MATERIAL AND METHODS**

**Population**

A cross-sectional study was conducted in a probabilistic sample at the “La Granja” mining project located at 2,020 m.a.s.l. in the Cajamarca-Peru region. The group of study subjects consisted of 4x4 truck drivers within the mining area and neighboring communities who exclusively worked day shifts with variable rotations and alternating work and rest days. The total study population consisted of 70 truck drivers. The shifts began at 07:30 hours and ended at 19:30 hours, with a two-hour lunch break. The number of effective driving hours during the work shift was between six and eight hours. Rest policies mandated drivers to fully stop their vehicles for 10 minutes after two hours of uninterrupted driving. In order to acclimate to the altitude, the drivers rest on the first day of their workweek and sleep at the campsite for the remainder of workweek.

The two-person bedrooms were comfortable, free of noise, and maintained at a pleasant temperature. The internal mine regulations mandated that workers eat their last meal before 20:00 hours and go to their bedrooms to fall asleep before 22:00 hours. The following day, they awoke between 06:30 and 07:00 hours. None of the workers were allowed to work if they did not spend the previous night at the campsite bedrooms or at a hotel assigned for these purposes. There was no exposure to alcohol, drugs, or intercurrent illness that disturbed the normal sleep pattern. The mine’s safety rules include random alcohol and drugs screening test.

No worker had received acetazolamide or oxygen therapy for four weeks prior to the test. The criteria for exclusion from the study analysis included a recording period of less than six hours and/or a trace failure of greater than or equal to 5% of the total recording period in either channel. The participants had not had a prior sleep-monitoring recording and were not currently undergoing treatment with positional, oral, or positive pressure devices. No driver had prior history of upper airway surgery due to snoring or SAHS.

The following variables were considered for all drivers: age, gender, weight, height, neck circumference, birthplace, and place of residence during non-work or rest period days. The altitudes of the drivers’ birthplaces or of their residences were calculated using available data from the Peruvian National Geographic Institute (http://www.ign.gob.pe/).

**Questionnaires**

All participants answered the modified Peruvian version of the Epworth Sleepiness Scale (ESS) questionnaires \(^{(19)}\) and the Lake Louise Acute Mountain Syndrome (AMS) Questionnaire \(^{(20,21)}\).

**Respiratory polygraph (RP) recordings**

The Apnea Link Plus respiratory polygraph instrument manufactured by ResMed™ was utilized in this study. This device has sensors to measure the following variables: nasal flow and snoring using nasal cannula pressure, thoracic respiratory effort using a pneumatic sensor, and pulse frequency and 

\(\text{Sao}_2\) using a fingertip pulse oximeter sampled at 1 Hz. The device is classified as a type 3 instrument according to the American Association of Sleep Medicine (AASM) classification. \(^{(22)}\) The results from the instrument validation compared to polysomnography have been documented on the manufacturer’s white paper. ResMed™ version 9.2 was used.

The polygraph was conducted in the bedrooms assigned to each worker within the mining campsite during their work days and nightly sleep hours. A polysomnographic nurse installed the device. The drivers ingested their evening meals at the usual time, and the consumption of caffeine-based substances was not allowed four hours before sleep time. Televisions, computers, electronic tablets, and cell phones were turned off throughout the night. The next morning, the RP devices were removed and the information was saved to a laptop computer and an external hard drive as a backup. Each test was reviewed and scored by a sleep specialist. Each driver had only one polygraph test recording. The analysis was performed automatically as well as manually. The original software was used for the automatic analysis, while the latter was performed after a complete recording review.

For scoring purposes, the Spanish Sleep Group criteria \(^{(26)}\) were followed for obstructive apnea, central apnea, mixed apnea, and obstructive hypopnea. The criteria defined by the AASM were used for the scoring of the Cheyne-Stokes pattern, as well as for determining the presence of altitude-induced central sleep apnea (CSA). The criteria were as follows: (a) three consecutive cycles during respiratory amplitude with a crescendo and decrescendo pattern; (b) five or more episodes of central apnea or hypopnea per hour; and (c) a crescendo and...
decrescendo pattern lasting at least 10 consecutive minutes with central respiratory events during more than 50% of the cases\textsuperscript{(25)}. Central hypopnea was determined based on whether the event was characterized by a decrease in the signal amplitude of the nasal cannula without flattening and a simultaneous reduction in thoracic effort. If the apnea-hypopnea index (AHI) was $\geq 10$ and predominantly obstructive events were observed in at least 70% of the instances, a subject was considered to have suspected SAHS.

Statistical analysis
The Stata 10.0 software (STATA Corp, College Station, Texas, U.S.A.) was used for the descriptive statistical analysis of the quantitative (mean and standard deviation or median and 25th and 75th percentile) and categorical variables (frequency). The Mann-Whitney U-test was used to compare continuous variables in two independent populations. For more than two independent populations, the Kruskal-Wallis H-test was used. The Chi-squared test was used for categorical variables. Pearson or Spearman correlation tests were used to determine the relationship between two continuous variables where appropriate.

After the RPs were conducted and reviewed by a specialist, the diagnoses were assigned to each subject. Based on the diagnoses, the tests were divided into two groups: normal tests, for those with normal RPs, and pathologic tests, for those with abnormal RPs (SAHS and CSA). A unique multiple logistic regression model, in which each independent variable was entered in a single step, was conducted to assess whether any demographic variable could predict the outcome of the RP test. The pathological test was considered the dependent variable, while age, gender, body mass index, neck circumference, and ESS scores were considered independent variables. The Pearson correlation and Bland-Altman test\textsuperscript{(26)} were used to validate the automatic scoring system by comparing the AHI obtained by the automatic method to the manual method. $P$-value $< 0.05$ was considered statistically significant.

Ethical considerations
All workers voluntarily consented to participate in the study by signing an informed consent previously approved by the Bioethics Committee of the Clínica Anglo Americana in Lima. Independently, the Committee on Ethics in Biomedical Research of the Hospital Nacional Dos de Mayo del Ministerio de Salud approved and authorized the execution of the study (Evaluation N° 042-2012-CEIB-AI-OACDI-HNDM).

RESULTS
A total of 63 RP tests were conducted, of which two (3%) involved technical failures during tracing. One study was excluded due to short recording time, and in another study, a worker removes the nasal cannula pressure. Finally a total of 59 studies were analyzed, representing 84% of the initial population.

When the RP data from the final sample were analyzed, 46 (78%) of the tests were normal, 7 (12%) exhibited a CSA pattern, and 6 (10%) presented with SAHS. The drivers’ demographic characteristics are presented in Table 1. All subjects were male. All were born in, live, and reside during their rest periods in different altitude zones. All values obtained from the questionnaires, such as ESS and LLQ, in those with normal RPs, CSA, and SAHS were within the normal ranges. There was no statistically significant difference between the three groups (Table 1).

The RP recordings were conducted between the first and second nights of their work shifts. During their rest days, six out of the seven (85%) drivers with CSA slept at a lower altitude than the mining campsite. This group was intermittently exposed to different altitude. In the normal study cases, only 21 out of 46 patients (46%) were intermittently exposed to different altitude, which was significantly different ($p = 0.035$) from the CSA group.

The Pearson correlation coefficient was calculated to compare the AHI obtained using the automatic method to the AHI obtained with the manual method (Figure 1A). The same calculation was conducted for the central apnea index (CAI) (Figure 1B). Furthermore, the Spearman correlation coefficient was calculated for the seven cases with CSA to compare the CAI obtained with the automatic method to the one obtained using the manual method (Figure 1C). Figure 2 presents the results of the Bland-Altman analysis for the comparison of the AHI obtained using the automatic versus manual method for all of the tests. No incidents or accidents while driving three days prior and one day after the RPs were reported.

Table 2 lists the RP variables calculated using the manual method. In the normal test group, all oxygen saturation values obtained from the recordings were low compared to the levels normally measured during polysomnography or RP tests at sea level. In the CSA group, the values for AHI, oxygen desaturation index (ODI), average $\text{SatO}_2$, $\text{Hb}$, $\text{MaxDesat}$, $T \leq 90$, $T \leq 85$, and $T \leq 80$ were more altered compared to the normal tests and SAHS subjects (Table 2). A greater number of respiratory events and oxygen saturation alterations were observed. The multiple logistic regression analysis was not able to determine any demographic variables that could independently predict a pathologic test. The analysis included the following variables: age, body mass index, neck circumference, and ESS score (Table 3).

DISCUSSION
All consensus documents regarding the diagnostic methodology clearly highlight polysomnography as the gold standard to identify sleep-disordered breathing\textsuperscript{(24,27)}. On the other hand, the use of simplified devices for sleep monitoring has allowed the implementation of simpler and less expensive methods with equally valid results\textsuperscript{(28-30)}. This type of equipment is currently used in clinical populations and extramural epidemiological studies\textsuperscript{(31-33)}. Considering the challenges posed by sleep monitoring in a population of truck drivers working at high altitude, we chose to implement RP testing. The proportion of failed tests was low. The study had good external validity, considering that RP studies were carried out in more than 80% of the study population.
Table 1. Demographic variables (n = 59, 100% males)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal (n = 46)</th>
<th>CSA (n = 7)</th>
<th>SAHS (n = 6)</th>
<th>p (^{¶})</th>
<th>All (n = 59)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>34.9 ± 8.9</td>
<td>37.3 ± 5.4</td>
<td>41.7 ± 9.0</td>
<td>0.193</td>
<td>35.8 ± 8.8</td>
</tr>
<tr>
<td>BMI (kg/m(^{2}))</td>
<td>26.0 ± 2.9</td>
<td>28.7 ± 3.2</td>
<td>27.0 ± 1.7</td>
<td>0.064</td>
<td>26.4 ± 2.9</td>
</tr>
<tr>
<td>NC (cm)</td>
<td>39.1 ± 2.3</td>
<td>42.1 ± 4.0</td>
<td>40.3 ± 2.5</td>
<td>0.108</td>
<td>39.6 ± 2.7</td>
</tr>
<tr>
<td>ESS</td>
<td>2.9 ± 2.6</td>
<td>3.4 ± 2.7</td>
<td>4.7 ± 3.7</td>
<td>0.447</td>
<td>3.2 ± 2.7</td>
</tr>
<tr>
<td>Lake Louise AMS Questionnaire</td>
<td>0.8 ± 1.3</td>
<td>0.4 ± 0.8</td>
<td>0.5 ± 1.2</td>
<td>0.932</td>
<td>0.7 ± 2.7</td>
</tr>
<tr>
<td>Altitude of city of birth (m.a.s.l.)</td>
<td>1698 ± 1227</td>
<td>2371 ± 259</td>
<td>1399 ± 1561</td>
<td>0.378</td>
<td>1748 ± 1203</td>
</tr>
<tr>
<td>Altitude of city of rest (m.a.s.l.)</td>
<td>1380 ± 1097</td>
<td>341 ± 828</td>
<td>800 ± 1101</td>
<td>0.058</td>
<td>1235 ± 1110</td>
</tr>
</tbody>
</table>

CSA: Altitude-induced Central Sleep Apnea; SAHS: Sleep Apnea-Hypopnea Syndrome; BMI: Body Mass Index; NC: Neck Circumference; ESS: Epworth Sleepiness Scale; m.a.s.l.: Meters above sea level; * Data shown as mean ± standard deviation; \(^{¶}\) Kruskal-Wallis H-Test: Normal = CSA = SAHS suspicion; # Kruskal-Wallis H-Test: Normal = CSA, p-value = 0.035.

Figure 1. Scatter plots. A: Comparison of the Apnea-Hypopnea Index (AHI) obtained with the automatic versus the manual method in the total population (n = 59); B: Comparison of the Central Apnea Index (CAI) obtained with the automatic versus the manual method in the total population (n = 59); C: Comparison of the CAI obtained with the automatic versus the manual method in the CSA (Altitude-induced Central Sleep Apnea) population (n = 7).

The Pearson analysis results and the Bland-Altman plots showed a correlation and an agreement between the automatic and manual methods of the RP instrument used in this study. This procedure is an operationally feasible alternative for use in remote areas that do not accommodate specialized sleep laboratories. Furthermore, the similarity between the automatic and manual methods allows for quick reviews and scoring of the events during the mandatory manual validation.

No driving incidents or accidents were reported on the day after the test, indicating that the use of these devices did not disturb quality of sleep or compromise driver safety at work.

The vast majority of drivers had low ESS scores and normal LLQ scores. It is well known that questionnaires conducted at the workplace have many limitations and must be interpreted within the context of drivers having a defensive attitude based on a desire to protect their jobs. This finding has been described in workers with SAHS, which is why the subjective information provided by the participants must be considered with caution.\(^{34}\)

SDB was documented in one-fifth of the study population. Sleep pathologies were proportionally divided into SAHS and CSA; however, the AHI severity was greater in the CSA cases. There is limited information about SAHS and its behavior at high altitude. It is known that the AHI decreases in patients who have mild to moderate SAHS and descend to lower altitudes. For this reason, conducting recordings after descent to lower altitudes leads to false negative results. Patz et al.\(^{35}\) originally described the decrease in the number of central apneas and hy-
Table 2. Polysomnographic variables obtained using the manual method (n = 59, 100% male)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normal (n = 46)</th>
<th>CSA (n = 7)</th>
<th>SAHS (n = 6)</th>
<th>p*</th>
<th>All (n = 59)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TRT</strong></td>
<td>470.1 ± 34.5</td>
<td>473.7 ± 22.7</td>
<td>475.3 ± 60.7</td>
<td>0.676</td>
<td>471.1 ± 36.1</td>
</tr>
<tr>
<td><strong>AHI</strong></td>
<td>4.0 ± 2.4</td>
<td>35.7 ± 19.3</td>
<td>12.5 ± 2.5</td>
<td>&lt; 0.001</td>
<td>8.7 ± 12.3</td>
</tr>
<tr>
<td><strong>AI</strong></td>
<td>1.0 ± 1.2</td>
<td>20.4 ± 16.3</td>
<td>3.3 ± 2.7</td>
<td>&lt; 0.001</td>
<td>3.6 ± 8.3</td>
</tr>
<tr>
<td><strong>OAI</strong></td>
<td>0.1 ± 0.3</td>
<td>5.3 ± 6.4</td>
<td>0.5 ± 0.5</td>
<td>&lt; 0.001</td>
<td>0.7 ± 2.7</td>
</tr>
<tr>
<td><strong>CAI</strong></td>
<td>0.9 ± 1.2</td>
<td>13.3 ± 14.3</td>
<td>2.8 ± 2.8</td>
<td>&lt; 0.001</td>
<td>2.6 ± 6.2</td>
</tr>
<tr>
<td><strong>MAI</strong></td>
<td>3.0 ± 2.2</td>
<td>15.3 ± 10.0</td>
<td>9.2 ± 3.8</td>
<td>&lt; 0.001</td>
<td>5.1 ± 5.8</td>
</tr>
<tr>
<td><strong>CHI</strong></td>
<td>6.5 ± 3.6</td>
<td>33.6 ± 17.2</td>
<td>15.3 ± 3.0</td>
<td>&lt; 0.001</td>
<td>10.6 ± 10.9</td>
</tr>
<tr>
<td><strong>ODI</strong></td>
<td>95.3 ± 1.5</td>
<td>94.4 ± 1.6</td>
<td>95.2 ± 1.6</td>
<td>0.439</td>
<td>95.2 ± 1.5</td>
</tr>
<tr>
<td><strong>Basal SatO₂Hb</strong></td>
<td>92.7 ± 1.4</td>
<td>90.9 ± 2.1</td>
<td>92.8 ± 1.6</td>
<td>0.048</td>
<td>92.5 ± 1.6</td>
</tr>
<tr>
<td><strong>AvgSatO₂Hb</strong></td>
<td>85.2 ± 6.2</td>
<td>79.9 ± 5.7</td>
<td>85.3 ± 1.0</td>
<td>0.021</td>
<td>84.6 ± 5.9</td>
</tr>
<tr>
<td><strong>MaxDesat</strong></td>
<td>11.8 ± 19.8</td>
<td>43.7 ± 31.1</td>
<td>12.8 ± 22.7</td>
<td>0.034</td>
<td>15.7 ± 23.6</td>
</tr>
<tr>
<td><strong>T90</strong></td>
<td>0.4 ± 1.5</td>
<td>4.9 ± 6.7</td>
<td>0.07 ± 0.01</td>
<td>&lt; 0.005</td>
<td>0.9 ± 2.9</td>
</tr>
<tr>
<td><strong>T80</strong></td>
<td>0.1 ± 0.4</td>
<td>1.0 ± 2.6</td>
<td>0.01 ± 0.01</td>
<td>&lt; 0.005</td>
<td>0.2 ± 0.9</td>
</tr>
<tr>
<td><strong>Avg FP</strong></td>
<td>60.5 ± 7.1</td>
<td>62.6 ± 6.9</td>
<td>68.5 ± 5.7</td>
<td>0.021</td>
<td>61.5 ± 7.2</td>
</tr>
</tbody>
</table>

CSA: Altitude-induced Central Sleep Apnea; SAHS: Sleep Apnea-Hypopnea Syndrome; NC: Not conducted; TRT: Total recording time; AHI: Apnea-Hypopnea Index; AI: Apnea Index; OAI: Obstructive Apnea Index; CAI: Central Apnea Index; MAI: Mixed Apnea Index; CHI: Central Hypopnea Index; ODI: Oxygen desaturation index; Basal SatO₂Hb: Basal oxygen saturation; AvgSatO₂Hb: Average oxygen saturation; MaxDesat: Lowest oxygen saturation; T90: Percent recording time with oxygen saturation ≤ 90%; T80: Percent recording time with oxygen saturation ≤ 80%; Avg PF: Average pulse frequency per minute.

* Data are presented as the mean ± standard deviation; † Mann-Whitney U-Test: Normal = CSA; ‡ Kruskal-Wallis H-Test: Normal = CSA = SAHS.

Table 3. Multiple logistic regression analysis.

<table>
<thead>
<tr>
<th>Variables*</th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.034</td>
<td>0.951 - 1.126</td>
<td>0.432</td>
</tr>
<tr>
<td>BMI</td>
<td>1.024</td>
<td>0.751 - 1.397</td>
<td>0.879</td>
</tr>
<tr>
<td>NC</td>
<td>1.362</td>
<td>0.988 - 1.879</td>
<td>0.059</td>
</tr>
<tr>
<td>ESS</td>
<td>1.156</td>
<td>0.899 - 1.487</td>
<td>0.257</td>
</tr>
</tbody>
</table>

OR: Odds Ratio; CI: Confidence Interval; BMI: Body Mass Index; NC: Neck Circumference; ESS: Epworth Sleepiness Scale; * The gender variable was not introduced in the analysis because 100% of the population was male.

popnea episodes as well as the proportional increase in the duration of obstructive apnea when sleep monitoring was conducted after descent from altitudes above 2,400 m.a.s.l. to 1,370 m.a.s.l.

The evaluation of patients after descent from high altitude to sea level does not allow for the proper stratification of disease severity or for the identification of central sleep apnea episodes, complicating the establishment of specific therapeutic guidelines. In a randomized study conducted by Nussbaumer-Ochsner et al., SAHS patients diagnosed at sea level using polysomnography and without therapeutic intervention with continuous positive airway pressure (CPAP) were exposed to different altitudes. The investigators reported a worsening of hypoxia and an increase in AHI during sleep, especially due to central apnea and hypopnea episodes. The aforementioned studies clearly show the different behavior of the disease depending on the altitude. There are no prospective cohort studies documenting the implications of these changes on drowsiness, quality of life, cardiovascular risks, or mortality. It is possible that the worsening and deepening of the intermittent oxygen desaturation plays an important role in the affected subjects.

CSA is a common phenomenon in healthy subjects exposed to high altitude. This pattern is very similar to that described by Cheyne-Stokes in patients with cardiac insufficiency or a compromised central nervous system, although their pathophysiologies are completely different. Miners traveling to high altitude have a higher incidence of CSA than do native individuals to high altitude locations. Thus, they are at greater risk of developing complications due to hypoxia while sleeping. It should be noted that AHI and CAI quantifications using type 3 instruments are calculated based on the total recording time. Conventional type 1 polysomnography is calculated based on the total sleep time. This difference in recording values can decrease the diagnostic sensitivity of the RP device. Therefore, the RP results tend to underestimate the magnitude of the aforementioned variables, raising the possibility that the SDB frequency or prevalence at high altitude could be higher.

The vast majority of workers with CSA recordings were intermittently exposed to high altitude because they alternated between working and resting states. The locations at which the workers usually rested were at lower altitudes compared to the altitude of the mining site. This would explain the RP findings during the first two nights at 2,020 m.a.s.l. As described previously, hypoxia exposure under these conditions compromises cognition. This effect could subsequently increase the risk of making errors, impair work performance, and compromise the workers’ safety, especially during the first two or three nights after ascending to a higher altitude. Exposure to high altitudes is associated with compromised quality of sleep, frequent awakening, reduction in REM sleep time, intermittent oxygen desaturation, and poor quality of wakefulness. Insomnia and a decrease in delta wave sleep have also been described.

CSA-related reports have indicated the altitudes at which this respiratory phenomenon occurs. The first description on record dates back to 1857, in the original reports of J. Tindall...
during his Mont Blanc expedition\textsuperscript{46}. The Scottish investigator described this phenomenon during a glacier study conducted at 3,500 m.a.s.l. Bloch et al.\textsuperscript{47} described the incidence of CSA as 21\% of the sleep time at 4,497 m.a.s.l. while scaling mount Muztagh Ata. Johnson et al.\textsuperscript{48} described this phenomenon in 2 out of 14 mountaineers at 1,400 m.a.s.l. while ascending the Himalayas. The findings in this last study, together with the results presented in our current study, show that CSA is not exclusive to healthy subjects exposed to altitudes above 2,500 m.a.s.l.

The multiple regression analysis did not discern predictive demographic variables that could identify abnormal RP recordings.

From a safety perspective, it is imperative to protect drivers who are at risk of accidents due to sleepiness caused by SDB. These drivers can be identified using objective sleep recordings as part of the pre-occupational test administered to applicants, as well as to currently employed drivers. Given the high prevalence of abnormal recordings that have been documented for the first time in Peru, it is very important to identify the presence of SDB in workers exposed to high altitude and in remote locations, which do not have access to conventional sleep laboratories.

At the end of our investigation (October 31 \textsuperscript{st} 2012), there were only nine sleep laboratories in all of Peru, with a total of 12 beds. These laboratories are all located at sea level in the city of Lima. The training of specialists working in cities with a high prevalence of this pathology is recommended, considering that more than 8 million Peruvians live at high altitude\textsuperscript{49}, as well as the remoteness of specialized sleep centers and the documentation of SDB including alterations due to high altitude and the inability to diagnose these disorders at sea level. In the meantime, it is unproductive to refer workers with suspected SDB living at high altitude to sea level laboratories to conduct sleep-monitoring recordings.

Based on our results, we recommend using RP recordings at the locations where the drivers work, ultimately referring them to a specialist. This proposal needs to be prospectively evaluated from operational, cost-benefit, and performance perspectives. Furthermore, it is crucial to incorporate information about SDB into the educational material for occupational health professionals. After a brief training period, these professionals could even participate in the recordings.

The main limitation of this study is the use of a simplified monitoring system, the RP, which is different from the accepted gold standard, the polysomnography. Regarding the comparative analysis between the automatic and manual modes, it is necessary to emphasize the limitations due to the absence of scattered points above 30 in the AHI range. The second limitation is related to the recordings conducted in drivers with CSA because these were conducted on the first work night, when the subjects had not had a chance to acclimate to high altitude. It is highly likely that the number of central apneas would be lower on subsequent nights. Regardless of this effect, the first nights after ascending to high altitude could involve impaired sleep quality and performance, as well as increased risk of driving accidents. This possibility could be the subject of another investigation.

The results described in this study indicate an increased prevalence of SDB, including both SAHS and CSA, in drivers with intermittent exposure to high altitudes. The prevalence might be even higher, considering that only the total recording time, and not the total sleep time, was taken into account. Our findings are relevant to the public health and occupational health fields, especially for populations that migrate to high altitudes and populations native to high altitudes that increasingly participate in extractive mining activities in Peru. These findings require validation by additional studies in similar populations.

Psychomotor surveillance tests could be an alternative tool to circumvent the limitations posed by the ESS or LLQ\textsuperscript{50}. We recommend using simple devices with respiratory effort sensors on job applicants as well as on subjects who are already working at high altitude. Polysomnography or RP recordings conducted at sea level are not able to identify specific sleep pattern alterations secondary to high altitude exposure, nor do they allow for the implementation of appropriate therapeutic measures.

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