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CASE REPORT

Ambulatory Recording of Physiological Variables During an Ascent of Mt Aconcagua

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The aim of this descriptive case study was to use an ambulatory biosensor system to capture data in real time in a harsh environment and to obtain continuous physiological measurements during an ascent of Argentina's Mt Aconcagua, the highest point in the Western Hemisphere. Between the 5800-m-high camp and the 6962-m summit, a 41-year-old male with previous high-altitude mountaineering experience was measured for minute-by-minute heart rate (60–154 beats/min), respiration rate (2–42 breaths/min), skin temperature (11.7–36.1°C), and core temperature (36.9–38.7°C) (1240 min of data: 417 min rest/sleep; 643 min ascent; 180 min descent). All of the measured variables were significantly correlated with each other ($p < 0.01$). There were incidences of "open leads" and "recovered data," indicating the potential for some aberrant data; however, data exist for each minute of the 1240 minutes of collection, and the values are within the expected physiological ranges. This study demonstrates the potential application of telemetry to monitor physiological variables during high altitude mountaineering.

Key words: mountaineering, trekking, high altitude, hypoxia, telemetry

Introduction

There is a wealth of information available about human physiology at high altitude. An entire chapter in exercise physiology texts is usually devoted to this topic. However, the majority of information available about humans exercising at extreme altitude has been obtained from studies done in the artificial environment of a hypobaric chamber. Typically, high-altitude field studies include data collected only under resting conditions or have involved some type of contrived or unnatural event, such as the classic study by Pugh et al[1] during which participants performed a maximal oxygen consumption test on an exercise bike at 7440 m on Mt Makalu. However, recent technological advances now make it possible to make ambulatory measurements in extreme environments; thus, physiological variables can be measured in mountaineers in real time as they are climbing.

Mt Aconcagua (6962 m), the highest point in the Western and Southern Hemispheres, provides an ideal location to track physiological variables during an ascent to extreme altitude. During the 2007 to 2008 climbing season, there were 4548 permits issued for summit attempts.[2] Although the most common climbing routes are not technically challenging, the summit success rate is low. Pesce et al[3] observed a 65% success rate over a 1-month period; however, various Internet sites suggest that only about 40% of climbers reach the summit, and veteran guide G. Benegas estimates the success rate to be no more than 30% (conversation, September 2010). Despite the popularity of climbing this peak and the obvious physiological challenge of reaching the summit, there are limited human physiology studies documenting this effort. Pesce and colleagues[3] administered a retrospective questionnaire to climbers in an effort to identify characteristics that were predictive of summit success. More recently, Snyder et al[4] monitored the ventilatory responses of 2 climbers during sleep at the various camps on Aconcagua. However, there has never been a study to assess the physiological demand of climbing Mt Aconcagua. Thus, the purpose of this descriptive case study was to use a telemetry system to continually record ambulatory data on several physiological variables (heart rate, respiration rate, skin temperature, and core temperature) during an ascent of Mt Aconcagua.

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Methods

PARTICIPANT

The participant was a 41-year-old male with previous mountaineering experience. He had been on more than a dozen expeditions above 6000 m with a previous altitude record of 7045 m. He had been residing at moderate altitude (1382 m) for 2 years prior to this expedition. The ascent was voluntary and self-funded. No medication of any kind (eg, acetazolamide) was taken during the expedition. The study was reviewed and approved by the Institutional Review Board of Utah State University.

PROCEDURES AND LOCATION

The expedition departed from Mendoza, Argentina (750 m) on January 31, 2008 with the first day of trekking on February 1. The trekking commenced from Penitentes (2600 m) and followed the Vacas valley for 3 days to a base camp at Plaza Argentina (4200 m). Two higher camps were established at 4950 and 5800 m. The mountain was climbed expedition style; there were multiple carries to the higher camps, and several days were spent at each camp to aid in acclimatization. The final ascent to the summit was via the Polish Traverse route.

Prior to the summit attempt while at high camp (5800 m), a wireless electrocardiogram (ECG)-signal processor (VitalSense-XHR, Philips Respironics, Bend, OR) was applied to the chest with 2 ECG pads to monitor heart rate and respiration rate. A dermal patch (Philips Respironics, Bend, OR) was applied to the dorsum of the left hand to measure skin temperature, and an ingestible capsule (Jonah™ capsule, Philips Respironics, Bend, OR) was swallowed to measure core temperature. Minute-by-minute transmissions from the ECG-signal processor, the dermal patch, and the ingestible capsule were integrated and stored to a monitor (VitalSense Integrated Physiological Monitor, Philips Respironics, Bend, OR) (see Figure 1) worn around the participant's waist. Heart rate, respiration rate, skin temperature, and core temperature were monitored continuously through the night at high camp, during the ascent to the summit, and during the descent back to high camp. The climber pressed an event marker button on the monitor defining the transitions from tent to ascent and then descent.

STATISTICAL ANALYSIS

The minute-by-minute data were categorized into rest/sleep, ascent, and descent segments and means ± SD were calculated. Significant relationships between measured variables were identified by Pearson product-moment correlations. The Statistical Package for the Social Sciences (SPSS, version 17.0, IBM, Chicago, IL) was used for all statistical analyses.

Figure 1. Components of the ambulatory monitoring system.

Results

The expedition spanned 16 days with the summit being reached on day 12. A total of 1240 min of minute-by-minute data for heart rate, respiration rate, skin temperature, and core temperature were obtained between the 5800-m-high camp and the 6962 m summit (see Table 1). This included approximately 417 min of data from inside the tent prior to the summit attempt, 643 min of data during the ascent and while on the summit, and 180 min of data during the descent. Heart rate and respiration rate during the ascent and descent were about double their respective rates while at rest inside the tent. On average, the skin temperature during the ascent and descent was about 10°C cooler than while at rest in the tent, and the core temperature did not vary by more than 1.77°C throughout the data collection. Heart rate, respiration rate, skin temperature, and core temperature were all significantly correlated to each other ($p < 0.01$).

There was a value associated with each physiological variable assessed for each minute of the 1240 min of data collection; there were no missing data when considering minute averages. However, there were 389 reports of "open leads," indicating a momentary disconnect, creating a potential inconsistency between some individual data points. If the monitor was briefly out of range of a sensor and a data point was missed, the data point could be recovered with the next recording. There were 78 reports of "recovered data."

Discussion

Rarely has ambulatory, real-time recording occurred during mountaineering. Pomidori et al[5] monitored arterial