

ORIGINAL RESEARCH

# The 6-Minute Walk Test as a Predictor of Summit Success on Denali

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**Objective.**—To test whether the 6-minute walk test (6MWT), including postexercise vital sign measurements and distance walked, predicts summit success on Denali, AK.

**Methods.**—This was a prospective observational study of healthy volunteers between the ages of 18 and 65 years who had been at 4267 m for less than 24 hours on Denali. Physiologic measurements were made after the 6MWT. Subjects then attempted to summit at their own pace and, at the time of descent, completed a Lake Louise Acute Mountain Sickness Questionnaire and reported maximum elevation reached.

**Results.**—One hundred twenty-one participants enrolled in the study. Data were collected on 111 subjects (92% response rate), of whom 60% summited. On univariate analysis, there was no association between any postexercise vital sign and summit success. Specifically, there was no significant difference in the mean postexercise peripheral oxygen saturation (SpO<sub>2</sub>) between summiters (75%) and nonsummiters (74%; 95% CI, -3 to 1;  $P = .37$ ). The distance a subject walked in 6 minutes (6MWTD) was longer in summiters (617 m) compared with nonsummiters (560 m; 95% CI, 7.6 to 106;  $P = .02$ ). However, this significance was not maintained on a multivariate analysis performed to control for age, sex, and guide status ( $P = .08$ ), leading to the conclusion that 6MWTD was not a robust predictor of summit success.

**Conclusions.**—This study did not show a correlation between postexercise oxygen saturation or 6MWTD and summit success on Denali.

*Key words:* 6-minute walk test, exercise test, altitude sickness, mountaineering, hypoxia

## Introduction

Thousands of people travel to elevations higher than 5500 m each year, many of whom attempt to reach the summits of mountains. Many factors contribute to summit success, including physical conditioning, technical skills, weather conditions, avoiding high altitude-related illnesses, and luck. Of persons who travel to these high altitudes, 35% to 90% travel as part of a guided expedition.<sup>1,2</sup> Mountain guides are often faced with the difficult task of anticipating which members of their group will have difficulty at higher elevations. In recent years, there has been substantial interest in screening climbers before their ascents on the popular mountains of the world. For example, climbers in Argentina on

Aconcagua (6962 m) are required to participate in a health screening examination program before ascent.<sup>3</sup> Proper screening has the potential to identify at-risk climbers and thereby decrease the need for high altitude rescues. Rescues conducted at high altitude can be dangerous and expensive, with rescues on Denali averaging \$12,000 per search and rescue response.<sup>4</sup> At 6190 m, Denali is the tallest mountain in North America. It attracts on average 1200 climbers a year, of whom 52% summit and 30% experience acute mountain sickness (AMS).<sup>5,6</sup>

Anecdotal evidence suggests that many mountain guides now carry fingertip pulse oximeters to measure their clients' peripheral oxygen saturations (SpO<sub>2</sub>) and use these measurements to predict performance at higher elevations. Many guides and climbers apply the reasoning that a "low" SpO<sub>2</sub> predicts poorer acclimatization, functional limitations at higher elevations, and a lower

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chance of summiting. However, there is no consensus on what  $SpO_2$  value correlates with these outcomes. Furthermore, data on pulse oximetry as a predictor of summit success are not conclusive. Some studies have shown significant correlation between a person's resting  $SpO_2$  and his or her subsequent development of AMS,<sup>3,7-9</sup> whereas others have shown no correlation.<sup>10,11</sup> Recent studies have shown that postexercise  $SpO_2$  may be a more reliable indicator of functional capacity—a climber's ability to acclimatize and exercise at high altitude—and predicts both development of AMS and summit success.<sup>8,12-15</sup>

A prospective study examining  $SpO_2$  after a 6-minute walk test (6MWT) and summit success was conducted by Lazio et al<sup>13</sup> at 4365 m on Aconcagua. Researchers obtained baseline vital signs, had subjects walk as fast as they could without running for 6 minutes, repeated the vital sign measurements after this period of exercise, and recorded the maximum distance walked (6MWT). The 6MWT is a well-validated assessment of a person's functional capacity. It has been used extensively since the 1970s to evaluate aerobic exercise capacity, treatment outcomes, and mortality in patients with a multitude of ailments including cardiovascular disease, chronic obstructive pulmonary disease, muscular dystrophy, pulmonary hypertension, and cystic fibrosis. An increase in 6MWT has been shown to be a reliable indicator of a patient's improving lung function after undergoing pulmonary rehabilitation.<sup>16</sup> 6MWT has also been shown to correlate with peak oxygen uptake, disease severity, and overall mortality in patients with congestive heart failure and chronic obstructive pulmonary disease.<sup>17-19</sup> Before the study by Lazio et al,<sup>13</sup> the 6MWT had never before been tested as a predictor of functional capacity in high altitude mountaineers.<sup>16,17,20</sup> Lazio et al<sup>13</sup> found that in the 64 subjects with complete data,  $SpO_2$  after the 6MWT (postexercise  $SpO_2$ ) was significantly lower in persons who failed to reach the summit compared with those who summited. Of note, they did not find any significant difference between the 2 groups in the distance a subject walked in 6 minutes. They concluded that postexercise  $SpO_2$  less than 75% had 97.2% sensitivity and 32.1% specificity in predicting failure to reach the summit.<sup>13</sup>

The goal of our study was to evaluate the 6MWT as a predictor of summit success in healthy mountaineers on Denali. We hypothesized that climbers who failed to reach the summit would have a significantly lower postexercise  $SpO_2$  than would those who attained the summit.

## Materials and Methods

### ETHICAL APPROVAL

The Institutional Review Board of Stanford University School of Medicine (IRB No. 6208, Panel 8) and the

Denali National Park Service (Permit No. 945) granted approval of human subjects research. All subjects signed a document of informed consent before taking part in this study.

### STUDY DESIGN

This study was conducted between June 12 and July 5, 2013, in Denali National Park, AK. Data were collected on Denali at the 4267 m camp (14 Camp). This camp is a starting point for many different routes on the mountain, with the great majority of climbers attempting the standard West Buttress route. Inclusion criteria were all willing climbers between the ages of 18 and 65 years who had taken 10 days or less to reach 14 Camp, were not pregnant, and had no significant pre-existing cardiopulmonary disease. Subjects participated on a voluntary basis and received no financial compensation.

A flyer advertising the study was distributed by the National Park Service to all registered climbers before their climb. Researchers then directly informed climbers about the study on their arrival at 14 Camp. Subjects who agreed to volunteer were enrolled within 24 hours of reaching 14 Camp. They were seated in a research tent, informed about the study, signed an informed consent document, and then completed a demographics questionnaire and Lake Louise Questionnaire (pre-LLQ), the latter to determine the presence of AMS.<sup>21</sup> Demographic data included age, sex, whether the subject was guided, whether the subject was working as a professional guide, prior history of altitude illness, use of acetazolamide, use of ibuprofen, the subject's altitude of residence, the number of days the subject took to reach 14 Camp, and the number of hours the subject had been at 14 Camp at the time of testing.

### 6-MINUTE WALK TEST

The 6MWT replicated the methodology of Lazio et al.<sup>13</sup> After completing the demographics questionnaire and pre-LLQ, subjects remained seated for a minimum of 5 minutes, after which heart rate (HR), respiratory rate (RR), and peripheral capillary oxygen saturation ( $SpO_2$ ) were measured and recorded. HR, RR, and  $SpO_2$  are henceforth referred to as vital signs (VS). Peripheral  $SpO_2$  and HR were obtained from a fingertip pulse oximeter (Onyx 9590, Nonin Medical Inc; Plymouth, MN). Subjects wore warm mittens before pulse oximetry so that digits would be well perfused. One investigator recorded  $SpO_2$  and HR at the end of the 5-minute rest period, with RR counted manually over 30 seconds.

The 6MWT was conducted on a 157 m rectangular outdoor course on packed snow with minimal elevation change. The course was packed daily and probed

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