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Effects of age and gender on success and death of mountaineers on Mount Everest

Raymond B. Huey[1,*], Richard Salisbury[2], Jane-Ling Wang[3] and Meng Mao[3]

[1]*Department of Biology, University of Washington, Seattle, WA 98195, USA*
[2]*Information Technology Division (retired), University of Michigan, Ann Arbor, MI 48109, USA*
[3]*Department of Statistics, University of California, Davis, CA 95616, USA*
**Author for correspondence (hueyrb@u.washington.edu).*

Increasing numbers of climbers are attempting Mount Everest, the highest mountain on Earth. We compiled interview data and computed the probabilities of summiting and of dying as a function of climber age and gender (2211 climbers, spring season) for the period of 1990–2005. Men and women had similar odds of summiting and of dying. However, climbers older than 40 years have reduced odds of summiting, and those older than 60 years have increased odds of dying, especially when descending from the summit. On Mount Everest, phenotypic selection appears blind to gender but favours young mountaineers.

Keywords: gender differences; hypoxia; mountaineering; senescence

1. INTRODUCTION

Each year approximately 1500 mountaineers venture to the Himalayan peaks of Nepal (Salisbury 2004). Their triumphs and tragedies have attracted international attention for nearly a century, but a climber's odds of summiting or of dying have rarely been quantified (Town 1986; Pollard & Clarke 1988; Huey & Eguskitza 2000; Huey *et al.* 2001; Huey & Salisbury 2003). In particular, whether those odds differ by age or gender has never been examined and is challenging to predict. With respect to gender, world athletic records of men exceed those of women in sports such as track and field, yet men and women perform similarly in hypoxia and cold (Wagner *et al.* 1979; Wagner & Horvath 1985; Ward *et al.* 2000; Roach & Kayser 2001; Schneider *et al.* 2002). With respect to age, younger mountaineers might be physically (Dill *et al.* 1980; Smolander 2002; Burtscher 2004; Tsianos *et al.* 2006) better able to survive in these hostile environments (West 1984), yet older mountaineers might offset diminution of physical ability by judgement and skill gained from years of experience.

Here we study climbers on Mount Everest, the world's highest peak. We calculated whether the odds of summiting or of dying differ by age and gender, and whether those odds have changed in recent years. Over 450 climbers are attempting Everest annually, and an increasing proportion are women and older climbers; thus, statistical power is sufficient to explore gender- and age-dependent patterns. Moreover, data are reliable and consistent, as they were obtained by a single rigorous interviewer (Salisbury 2004; McDonald 2005).

2. MATERIAL AND METHODS

Mountaineering data were obtained by Elizabeth Hawley, who collected them via intensive interviews and correspondence over four decades (McDonald 2005). Her archives were converted into a database by Salisbury (2004). We analysed data for mountaineers ($n=2211$, 1990–2005) making their first attempt on Everest, thereby avoiding non-independence. We included only 'members' on climbing permits and thus excluded high-altitude assistants and porters, who have different responsibilities (and for whom age is often unknown). Chinese expeditions were also excluded, as local authorities do not distinguish members and porters. Data are for spring, when most attempts are made (77.9% of climbers between 1990 and 2005), and for climbers (88.2% of spring climbers) using a main 'commercial' route (Salisbury 2004); other routes are rarely attempted and are relatively difficult and dangerous (Huey & Salisbury 2003). Age and gender were known for most climbers (98.4 and 100%, respectively). We defined the level of prior experience (0, 1) based on whether a climber had previously attempted a Nepalese peak, as mountaineering experience elsewhere is unknown. Even though climbers usually climb in teams (Huey & Eguskitza 2000), we treated individual climbers as independent because we are analysing attributes (e.g. age, gender) of individuals.

(a) *Statistical analyses*

Exploratory analyses suggested that rates (e.g. of summiting) were nonlinearly related to age and appeared to show a 'breakpoint', an age at which rates shifted abruptly. A non-parametric approach based on generalized additive models (GAMs, Hastie & Tibshirani 1990) confirmed that log odds were nonlinearly related to age and showed a breakpoint. Thus, logistic regression is unsuitable; instead, we used joint-point models, where log odds are piecewise linear at the breakpoint. Specifically, we report quasi-binomial models (generalized linear models, GLMs, with a dispersion parameter) with factors (gender, prior experience and route), a joint-point model for age and year of climb as a covariate. A route factor partitioned attempts via the Southeast Ridge in Nepal versus those from Tibet ($n=878$ and 1333, respectively; see Huey & Salisbury 2003). Interactions were non-significant. In analyses of death rates, year of climb had significant nonlinear effects; thus, we used semi-parametric GAMs that were similar to GLMs, but including a non-parametric effect of year. Statistics were computed in R (Ihaka & Gentleman 1996).

3. RESULTS

The gender ratio and age structure on Everest has been shifting since the first ascent in 1953. Men still outnumber women, but women are increasing in proportion ($p \ll 0.001$; table 1) and constituted approximately 10% of all climbers between 2000 and 2005. The 'greying' of mountaineers on Everest is also apparent (table 1). In the early decades, 18.7% of climbers were equal to or older than 40 years (the age at which summit rate begins to drop; figure 1*a*) and only 0.3% were equal to or older than 60 years (the age at which death rates increase; figure 1). In recent years (2000–2005), 45.6% were 40 years old and above and 3.6% were 60 years old and above. In particular, 12.5 sexagenarians per year attempted Everest between 2000 and 2005.

For the period of 1990–2005, climbers ranged from 15 to 69 years (grey histogram; figure 1*b*), though 50% were between 31 and 43. Most (88.8%) were men and few (38.1%) had prior experience on a Nepalese peak, but men were slightly more likely to have prior experience than women (38.9% versus 32.0%, $p=0.041$). Prior experience increased

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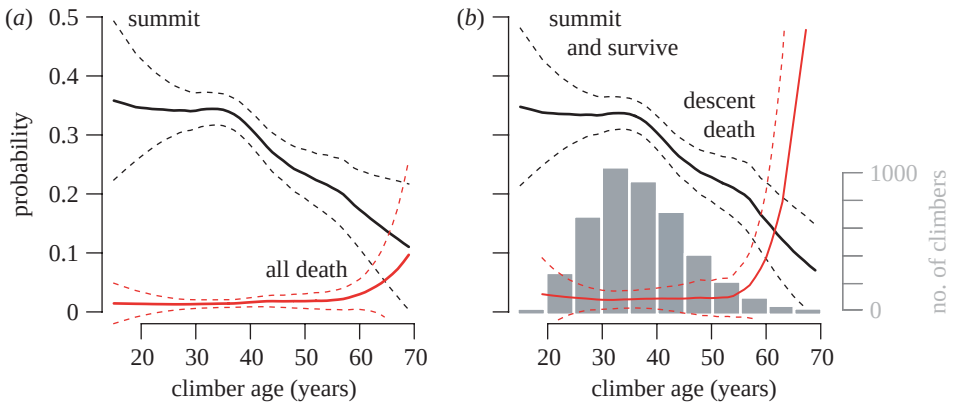

Figure 1. Senescence of mountaineers on Everest. (*a*) Probabilities of summiting (1990–2005; black line, ±95% CI) and of death (red line) anywhere on the mountain versus climber age. (*b*) Probabilities of success (black line, summiting and surviving) and of death during descent from the summit (red line), with a histogram of climber ages (grey). Curves are non-parametric GAM fits.

Table 1. Demographic shifts in mountaineers attempting Mount Everest between 1953 and 2005.

year	no. of women per year	percentage of women	no. of climbers, age > 39 years	percentage for age > 39 years	no. of climbers, age > 59 years	percentage for age > 59 years
1953–1989	2.8	4.7	11	18.7	0.2	0.2
1990–1999	21.3	8.5	85.8	34.5	3.1	1.2
2000–2005	35.7	10.3	159.5	45.6	12.5	3.6

significantly with age to approximately 30 years (GLM, $p<0.001$) but did not change thereafter ($p=0.93$). Even so, the difference in experience with age was relatively small (29.1% for age less than 30 years and 40.3% for age 30 years and above).

Overall odds of summiting were 30.7% ($n=722$) and those of dying were 1.5% ($n=36$). Death rate of climbers descending from the summit (2.35%, $n=17$) was nearly twice that of those who did not summit (1.2%, $p=0.048$). Success rate (joint probability of summiting and surviving) was 29.9%.

Chances of summiting changed little until the age of approximately 40 years ($p=0.19$), but then declined dramatically ($p\ll0.001$; figure 1*a*). We used a GLM joint-point model (for ages less than 40 years versus 40 years and above), which gave a better fit than did a model with age alone ($p=0.05$). Rate of summiting was independent of gender ($p=0.36$), as men and women had similar rates of summiting (30.9 and 28.3%, respectively). Rate of summiting increased between 1990 and 2005 as well as with prior experience (both $p\ll0.001$), and was higher on the Southeast Ridge ($p=0.03$) than on northern routes. GAMs gave similar results.

Overall death rate changed little until the age of approximately 60 years (1.5%, $p=0.53$) but then increased suggestively thereafter (5.0%; figure 1*a*). We fit a GAM joint-point regression model (less than 60 years versus 60 years and above). The increased death rate for older climbers was marginal ($p=0.07$), and the model only approached significance ($p=0.10$). Death rate was independent of gender ($p=0.91$), as men and women had similar death rates (1.62 and 1.63%, respectively). Death rate was also independent of experience and route (both $p>0.60$), but varied nonlinearly with year ($p=0.02$), primarily because many climbers died during the 1996 storm. In a parallel GLM analysis, the increased death rate for climbers older than 59 years was significant ($p=0.037$). A joint-point regression analysis was again suggestive ($p=0.10$). However, since only 60 climbers were sexagenarians and only three of them died, an increased overall death rate for sexagenarians is tentative.

A comparison of overall death rates underestimates risks facing older climbers, simply because very few older climbers reach extreme altitudes (figure 1*a*) where risk is greatest. To compare the death rates of climbers who reached equivalent altitudes, we analysed the death rates only of climbers descending from Everest's summit ($N=677$; figure 1*b*). We used a GAM joint-point regression that improved the fit ($p=0.001$). Descent death rate was essentially constant until the age of approximately 60 years ($p=0.89$) and then increased significantly ($p=0.0004$). Descent death rate was independent of gender (men 2.3%, women 4.3%, $p=0.20$) and experience ($p=0.43$), but varied nonlinearly with year ($p=0.006$), again reflecting storm deaths in 1996. Not surprisingly, the overall success rate (above) decreased steeply for climbers older than approximately 40 years ($p\ll0.001$; figure 1*b*) but did not differ between men and women (30.3 and 27.1%, respectively, $p=0.36$).

4. DISCUSSION

Over a half century has elapsed since the first ascent of Everest, and the number of climbers attempting Everest continues to grow. The number and proportion of women and older climbers are increasing (table 1), hence we examined whether a climber's odds of summiting or of dying varied by gender or

age. We found that women and men have similar odds of summiting, death overall and death during descent. In fact, none of these odds even approaches statistical significance, so this pattern is robust. Similarity of these odds may reflect similar physiological performances of men and women in hypoxia and cold (Wagner *et al.* 1979; Wagner & Horvath 1985; Ward *et al.* 2000; Roach & Kayser 2001), as well as similar resistance to acute mountain sickness (Schneider *et al.* 2002).

Older climbers are also increasing in number and proportion on Everest (table 1), probably reflecting general demographic and health trends (Burtscher 2004). However, climbers older than approximately 40 years clearly face an uphill battle to summit Everest (figure 1*a*), and those in their 60s achieve the summit far less frequently (13.3%) than do those in their 30s (35.7%). Older climbers may be less likely to summit because they are physically less capable (Moore 1975; Burtscher 2004; Tsianos *et al.* 2006) or they climb in a more conservative manner.

Climbers older than approximately 60 years also have elevated death rates (figure 1), which challenges a proposal (Kinoshita *et al.* 2000) that sexagenarians can safely climb 8000 m peaks. In fact, sexagenarians had an overall death rate approximately three times higher than that of younger climbers (5.0% versus 1.5%, risk ratio = 3.3, 95% CI 1.1–9.4), even though they rarely summit. Moreover, sexagenarians who summited had a descent death rate strikingly higher (25% versus 2.2%, $p = 0.015$; risk ratio = 11.1, 95% CI 3.0–31.7) than that of younger summiters (figure 1).

Climbers with prior experience on a Nepalese peak had elevated rates of summiting (38.7% versus 25.7%) though not a lower death rate (1.8% versus 1.5%). Increased odds of summiting might reflect direct benefits of prior experience (Kinoshita *et al.* 2000) or self-selection; perhaps only climbers who performed well on a lower peak later returned to attempt Everest.

When evaluating whether to attempt Everest, mountaineers should have access to quantitative data on their odds of summiting and of death. We find that these odds are independent of gender, but sensitive to age. On Everest, youth and vigour trump age and experience.

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