Effect of altitude on blood pressure and heart rate

Lyazzat Gumarova[1], Linda Sackett-Lundeen[2], Germaine Cornelissen[2]
1 Al-Farabi Kazakh National University, Almaty, Kazakhstan
2 Halberg Chronobiology Center, University of Minnesota, Minneapolis, MN, USA

Aim

To determine whether blood pressure (BP) and/or heart rate (HR) invariably increases in clinically healthy individuals in association with a relatively rapid change in altitude.

Introduction

Altitude is known to be somewhat of a load on the heart, which is minimal at rest but can be significant during exercise. It is not uncommon for lowland residents to temporarily experience an elevation in BP at high altitude, because lower oxygen levels at higher altitude may be associated with an increase in adrenaline. It can take up to 1 or 2 weeks before acclimatization to altitude occurs and BP returns to usual values. It has been reported that 416 sudden cardiac deaths accounted for about 30% of all deaths involving mountain sports, the risk increasing with advancing age and being gender-dependent.

Subjects and Methods

The study included 12 clinically healthy volunteers, 19-54 years of age, residents of Almaty, Kazakhstan (787m). They drove by car or bus to the most popular attractions in the mountains with altitude 1691, 2260, or 2735m. Before starting their hike, they were instructed to take a measurement of BP and HR while sitting, using the ABPM they had been using for 1-3 days prior to the trip (Figure 1). Both ABPM and concomitant actigraphy lasted for at least another 24 hours after returning to the city. Each record was analyzed chronobiologically to yield estimates of the circadian rhythm parameters. Differences between measurements taken in the mountain and either the global rhythm-adjusted mean value (MESOR, M) or the global daytime average (dx) were computed and further analyzed by paired t-test and linear regression as a function of altitude, M, or dx. A one-way ANOVA was also performed to examine whether the change in BP and/or HR depended on the change in altitude and time of day in the mountain.

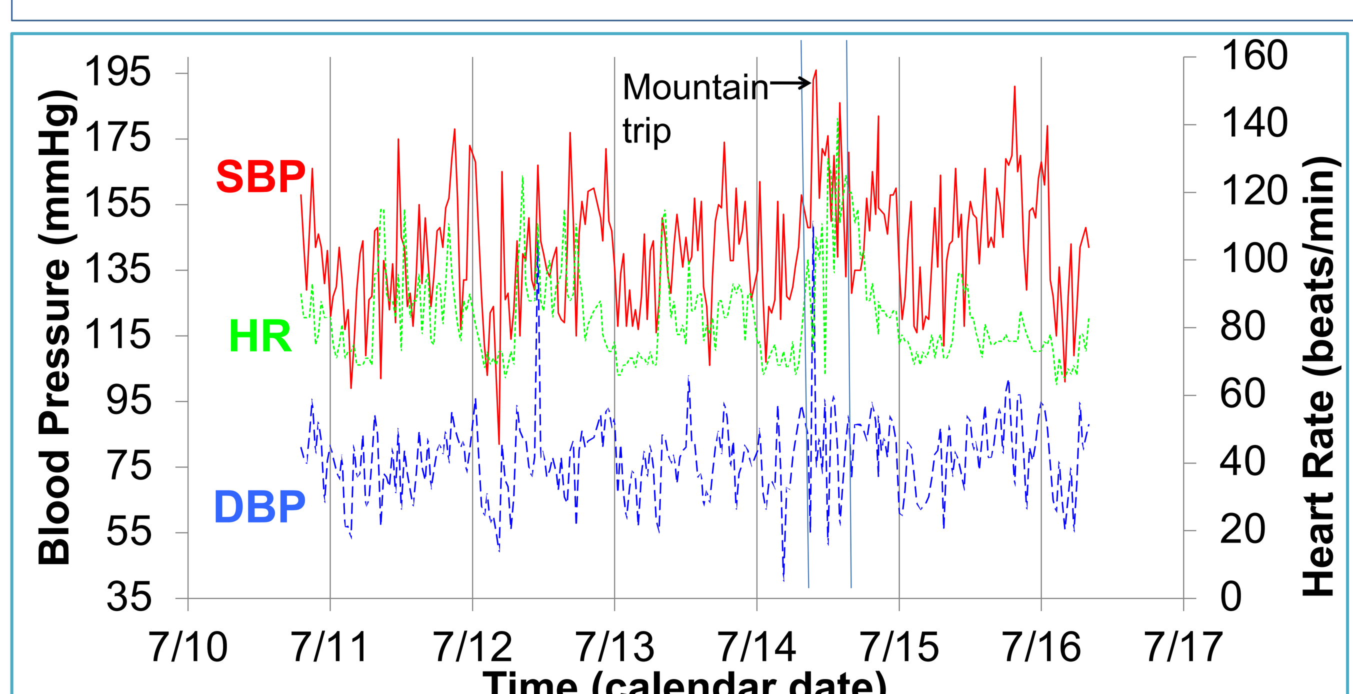

Figure 1: SBP, DBP, and HR of one participant (F, 54y).

Results

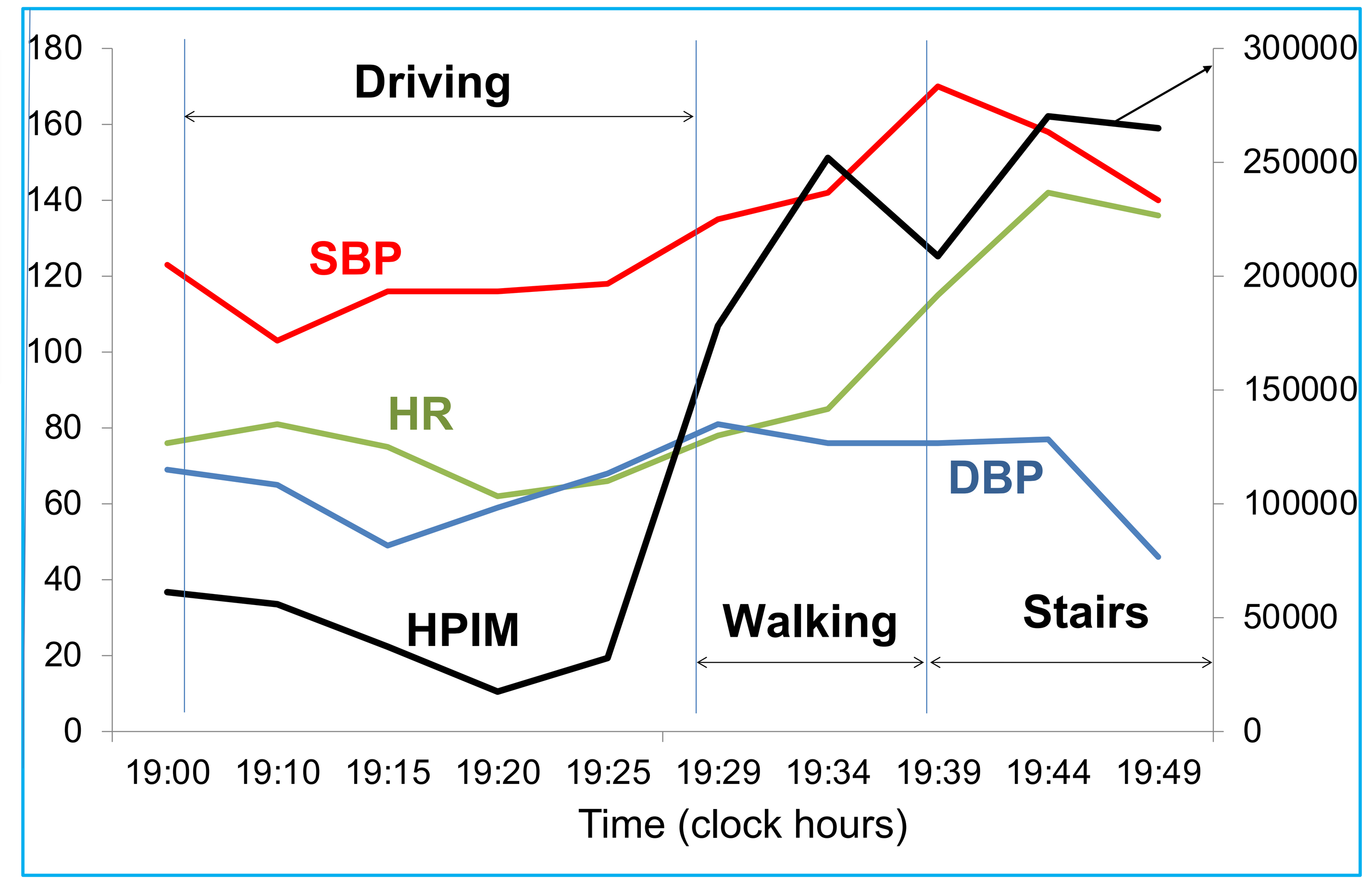

Figure 2: Changes in HPIM (actigraphy, AU), SBP (mmHg), DBP (mmHg), and HR (bpm) of one study participant during short-term trip to the mountains (M, 19y).

Figure 2 illustrates changes in activity, BP and HR in the case of a young man. On the average, relative to the MESOR, systolic (S) and diastolic (D) BP increased in the mountain (mean ± SE, SBP: 17.3 ± 7.7 mmHg, t = 2.243, P=0.046; DBP: 7.8 ± 6.1 mmHg, t = 1.279, NS), as did HR (12.1 ± 4.0 bpm, t = 3.045, P=0.011), Figure 3.

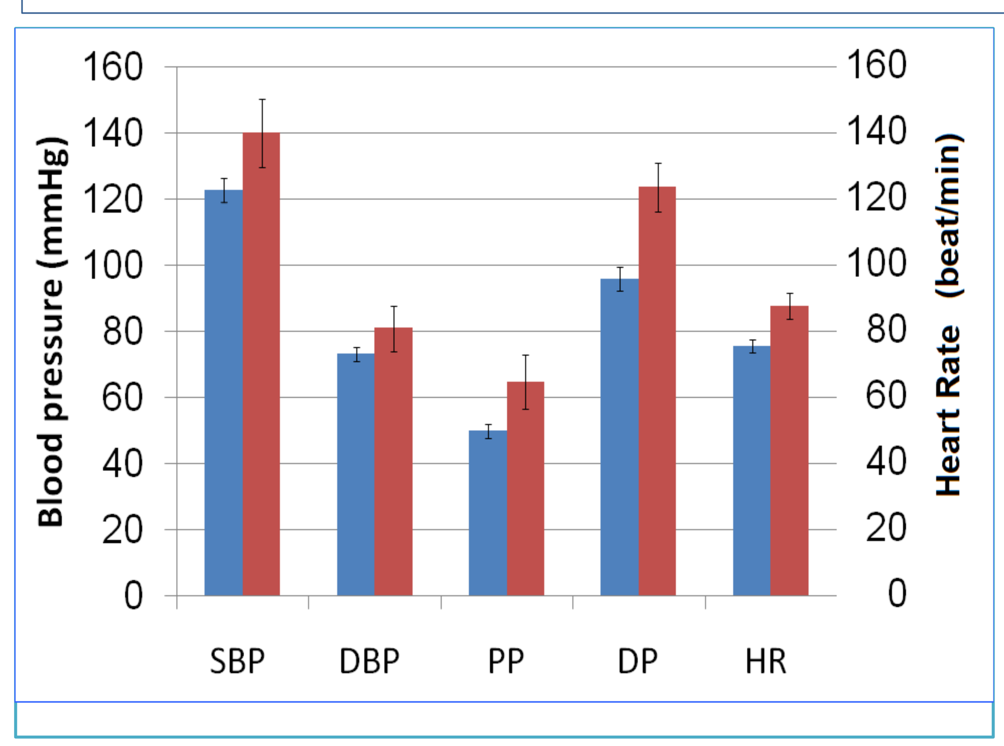

Figure 3: SBP, DBP, Pulse Pressure (PP), SBPxHR/100 (DP) and HR are higher at high (red) versus low (blue) altitude (mean ± SE).

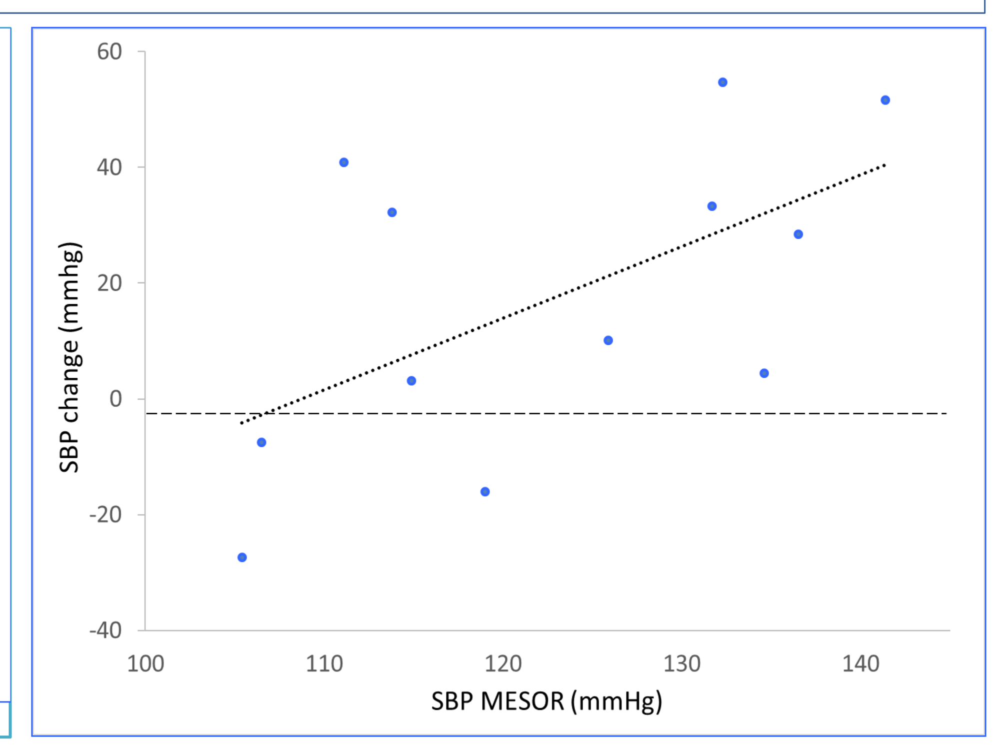

Figure 4: The SBP response to altitude increases with SBP at low altitude (r=0.578, P=0.049).

The SBP response to altitude was found to depend on SBP-M: the higher the MESOR of SBP, the larger the SBP response to the change in altitude (r=0.578, P=0.049), Figure 4. The BP response was also positively related to the extent of altitude change, relative to M (SBP: r=0.527, P=0.078; DBP: r=0.600, P=0.039) or to dx (SBP: r=0.619, P=0.032; DBP: r=0.633, P=0.027), Figure 4. In relation to dx, the SBP response to altitude was a large increase for those who went to the highest altitude in the morning and a decrease for those who went to the lowest altitude in the morning; a smaller increase was found for those who went to the lowest altitude in the afternoon (F=3.900, P=0.060), Figure 5.

Discussion & Conclusion

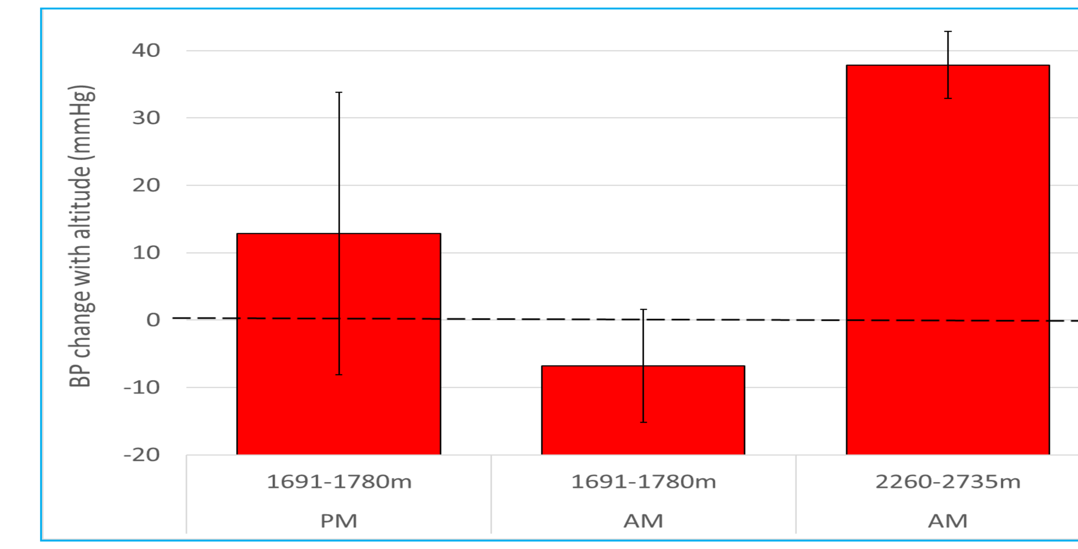

Figure 5: The SBP response to altitude increases with altitude and depends on circadian stage.

Similar results were obtained in an earlier study of 8 individuals who were monitored by ABPM for at least 24 hours during a conference in Copper Mountain, CO, USA (2,960 m) and continued monitoring for 24 hours or longer at their usual place of residence at much lower altitude, such as MN (253 m).
On the average, SBP increased by 10.0 ± 2.6 mmHg, t = 3.850, P=0.006), DBP by 3.6 ± 2.0 mmHg (t = 1.814, P=0.112), and HR by 4.0 ± 1.1 bpm (t = 3.668, P=0.008). The extent of BP change with altitude was also found to be positively correlated with the BP MESOR at low altitude (SBP: r=0.321; DBP: r=0.472), but the results did not reach statistical significance. When combining results from both studies, individuals with a higher SBP at low altitude were indeed found to respond to altitude with a larger increase in SBP(r=0.444, P=0.049; r=0.508, P=0.022) when differences in SBP are computed relative to M or dx, Figure 6.

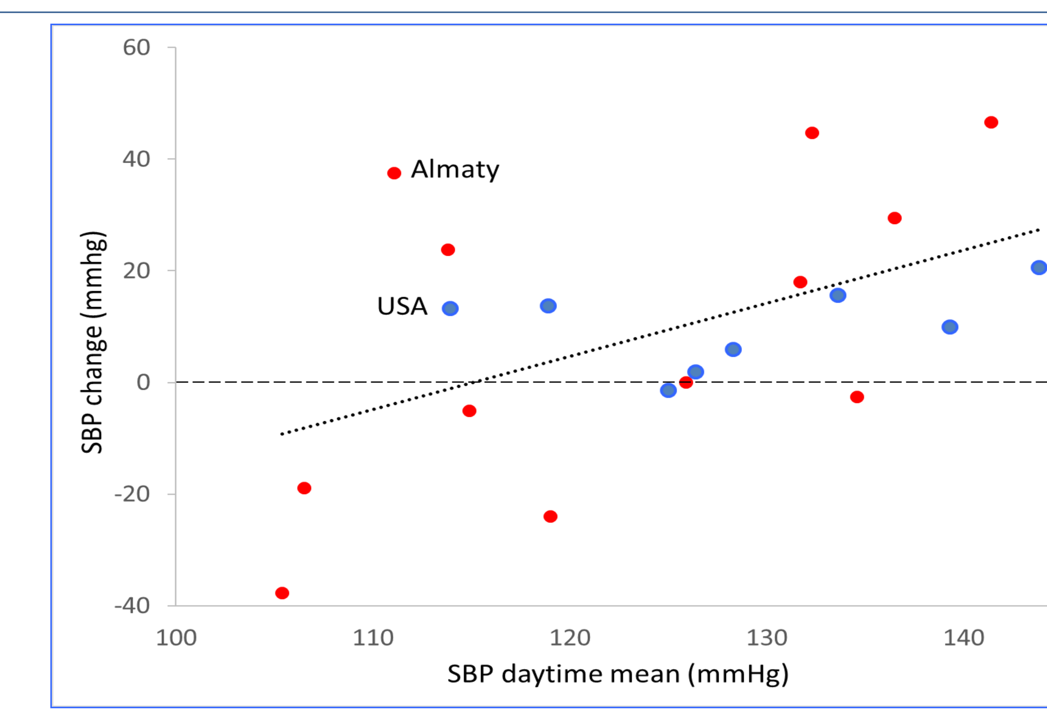

Figure 6: Confirmation of the SBP response to altitude as an increase with SBP at low altitude.

These results indicate that without any exertion, with measurements taken in the sitting position, BP is affected by altitude. While on average, BP increases with altitude, the response differs among individuals, those with a higher BP at low altitude responding with a larger increase in BP.

Contact

Lyazzat Gumarova and Germaine Cornelissen
Al-Farabi Kazakh National University, Almaty, Kazakhstan (LG); Halberg Chronobiology Center, University of Minnesota, Minneapolis, MN (GC)
Email: gumarova.lyazzat@gmail.com corne001@umn.edu
Website: http://halbergchronobiologycenter.umn.edu/
Phone: +7 7771815145 (LG); 612 624 6976 (GC)

References

1. Ryan BJ, Wachsmuth NB, Schmidt WF, Byrnes WC, Julian CG et al. Altitude Omics: Rapid Hemoglobin Mass Alterations with Early Acclimatization to and De-Acclimatization from 5260 m in Healthy Humans. PLoS ONE 2014; 9 (10): e108788.
2. Dietz TE, Hackett PT. High-Altitude Medicine. Travel Medicine (Fourth Edition) 2019; 387-400.
3. Burtscher M, Philadelphy M, Likar R. Sudden cardiac death during mountain hiking and downhill skiing. New England Journal of Medicine 1993; 329: 1738-1739.