Published in final edited form as:

Am J Hum Biol. 2015 January ; 27(1): 136–138. doi:10.1002/ajhb.22609.

Daily Environmental Differences in Blood Pressure and Heart Rate Variability in Healthy Premenopausal Women

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Abstract

Objectives—As daily environments change, behavior and activity also change and since blood pressure (BP) and heart rate (HR) are allostatically tied to these factors, one might expect that environments that elicit the greatest behavioral/activity variation should also evince the highest BP and HR variability (standard deviation (SD) or coefficient of variation (CV)). The purpose of this study was to evaluate this premise.

Methods—Two hundred and six women (age=37.6±9.1 years) wore an ambulatory BP monitor on a midweek workday. All worked in clerical, technical, or professional positions. Ambulatory BP and HR Means, SDs and CVs at work (11AM–3PM), home (approx. 6PM–10PM) and during sleep (approx. 10PM–6AM) were compared using repeated measures ANCOVA.

Results—Mean BP and HR decreased from work and home to sleep (121±11, 120±11 vs 107±12 systolic; 82±10, 80±11 vs 66±11 diastolic; 79±12, 80±12 vs 68±11 heart rate (all $p<0.001$)), while the CV of systolic and diastolic BP increased (0.06±0.02, 0.07±0.02 vs 0.08±0.03 systolic; 0.09±0.03, 0.10±0.04 vs 0.12±0.05 ($p<0.001$)). The HR SD decreased during sleep (8.1±3.8, 8.2±3.8 vs 6.9±3.2 ($p<0.001$)).

Conclusions—HR variability follows the expected variability pattern with behavior and activity, whereas BP does not.

Keywords

Ambulatory blood pressure variability; Heart rate variability; Women

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CONFLICT OF INTEREST: None

INTRODUCTION

Ambulatory blood pressure (BP) and heart rate (HR) variability, whether evaluated as the standard deviation of the measurements (SD) or in proportional terms as the coefficient of variation (CV), have been shown to be risk factors for cardiovascular morbidity and mortality (e.g. Palatini 1999; Kikuya et al. 2000; Hansen et al. 2010; Flores, 2013). These associations are typically based on measures assessed over twenty-four hours; however, many studies have shown that there are patterns of BP and HR variation within the daily framework, and that these patterns such as the waking-sleep difference, morning surge and variability across daily environments (such as work, home and during sleep) also predict cardiovascular morbid outcomes and are significant sources of the aggregate 24-hour variability risk (see James et al., 2004; Verdecchia et al, 2012; James, 2013, Flores, 2013).

The average BP and HR differences between environments over a day arise from the behavior and activities within them (James, 2013). Given that these will differ across environments, it would be expected that the environmental variability in BP and HR as reflected in the SD or CV would also be different, such that the environment with the greatest behavioral/activity variation would also have the highest BP and HR variability. The purpose of this study was to evaluate this premise in a sample of women employed outside the home.

METHODS

Subjects

A secondary analysis was conducted on ambulatory BP and HR data collected on 206 women that participated in a study investigating the stress related health risks of having family histories of breast cancer (see Dettenborn et al., 2005). The women were all employed in clerical, technical, or professional positions at one of three major medical centers in New York City. The measurements were aggregated within three daily environments (work, home and during sleep). The present and original study had IRB approval and all participants signed written informed consent. Subjects were excluded from the breast cancer study if they had HIV or cancer, could not speak English, were on medications other than oral contraceptives, or were taking part in other research which might compromise the variables within the study (Dettenborn et al., 2005). Table 1 shows selected characteristics of the present study's sample.

Procedures

As part of the family histories of breast cancer study protocol, each woman wore a Spacelabs 90207 ambulatory BP monitor during the course of one mid-week workday (Tuesday thru Thursday) between March 1998 and December 2000 (see James and Bovbjerg, 2012 for the breast cancer study design details). The monitors were calibrated to a mercury column when they were fitted at the beginning of the study day, after anthropometric measurements and demographic and questionnaire data were collected. Monitors were set to take measurements every 15 minutes from 8:00 AM to 10:00 PM and every 30 minutes from 10:00 PM to 8:00 AM the following morning (van Berge-Landry et

al., 2010). BPs (in mmHg) and HRs (in beats per minute (bpm)) were averaged at work (11:00 AM–3:00 PM), home (approximately 6:00 PM–10:00 PM) and during sleep (approximately 10:00 PM–6:00 AM). The time frames for the BP/HR averages were defined from a urine collection aspect of the study (see James and Bovbjerg, 2012). Daily environment and activities were determined from entries in a diary filled out during monitoring. Based on the diary reports, the proportion of BP/HR measurements taken during physically active (e.g. walking, doing household chores) and more quiescent (e.g. deskwork, talking, watching TV) activities were calculated for the work and home environments. Given the time frames and measurement frequency, it was expected that subjects would have 16 measurements within each environment. However, due to removal of artifactual readings (see Pickering et al. 1982) and variations in the timing when subjects actually arrived home and went to bed, there were 15.5 ± 3 measurements at work, 14.0 ± 4 measurements at home, and 14.8 ± 3 measurements during sleep. The SD and CV were calculated from the measurements in each environment. The CV was calculated as the SD divided by the mean. To evaluate whether there were differences in the level and variability of BP and HR across environments, repeated measures ANCOVA models were run with BMI as a covariate. Significance was considered $p < 0.05$.

RESULTS

The diary data revealed that the women were quite sedentary on the day of their study. Specifically, 90% of the measurements at work and 89.3% of the measurements at home were taken while the subjects were seated or reclining and engaging in more quiescent types of activity. As a consequence, there were few substantial activity transitions at either work or home.

Table 2 shows that mean levels of systolic and diastolic BP and HR declined from work and home to sleep ($p < 0.001$). However, the SD of systolic and diastolic BP tended to increase from work and home to sleep with the SD of systolic pressure at work being statistically less than that of sleep ($p < 0.01$). The CVs of systolic and diastolic BP at work and home were all significantly less than that during sleep ($p < 0.001$). Conversely, the absolute HR variability (SD) at work and home was significantly greater than that during sleep ($p < 0.001$), while there was no difference in the HR CVs across the environments. Finally, although not shown, BMI was positively associated with both BP and HR levels ($p < 0.05$).

DISCUSSION

The results show that while mean BPs are higher at work and home, the CVs are significantly lower than during sleep. Conversely, with HR, the means and SDs were both higher at work and home than during sleep, while the CV did not change. The HR data generally confirm expectations, whereas the BP data are opposite of what was expected.

The women in this study were largely sedentary at work and home, with about 90% of their activities being quiescent. Since the women reported few activity transitions, their BP and HR variation would likely be lessened. However, significant stress or mood related transitions should increase both BP and HR variation relative to measures during sleep (see

Zanstra and Johnson, 2011; James 2013 for discussion). As previously noted, HR variation is greater at work and home than during sleep; however, the fact that BP variation is actually less intimates that other factors must be increasing sleep BP variation.

Interestingly, other studies have found that sleep BP can be more variable than waking BP (see Flores, 2013). There are several factors that can substantially increase sleep BP variation. First, changing arm positions can cause substantial variation in ausculted BPs. Specifically, sleeping on the right side (when the monitored arm is above heart level) produces measurements that are 10 mmHg lower than when lying on the left side (when the monitored arm is below the heart level) (Schwan and Pavlek, 1989). Changing from a supine to prone position can also cause pressure to vary, and the difference in pressure from a supine to right side sleeping position can be as much as 15 mmHg (Schwan and Pavlek, 1989; Tabara et al., 2005). Second, it is also highly likely that a portion of "sleep" BPs as determined from diary entries are taken while the person is lying awake during the night, which would tend to increase the overall "sleep" pressure variation by increasing the upper limit of the "sleep" BP range. That is, recumbent waking pressures, while lower than those taken while sitting or standing, are still higher than those during recumbent sleep (James et al., 2001; James, 2007). Transitions through non-REM and REM sleep as well as phasic hypertensive events during REM sleep can also contribute to increased BP variability, although this variability is accompanied by surges in HR and thus increased HR variability (Silvani, 2008). Given the relative infrequency of the BP sampling and the fact that absolute HR variability declined with sleep in this study, it is unlikely that REM events contributed to our findings. Indeed, the fact that absolute HR variability declined could suggest that wearing a BP monitor overnight interferes with sleep quality in a way that decreases REM sleep.

Caution should be used in extrapolating the results of this study to the general population. Our study sample was limited to healthy women employed in a limited range of occupations, and thus it is quite possible that different results could be obtained in a demographically different group. Furthermore, while the sampling of BP measurements was similar across environments, the frequency of measurements during each was low, so that more frequent measurements could lead to different conclusions. Nonetheless, from the perspective of the study's premise, the HR results confirm expectations, whereas BP does not. Further research is needed to verify these results and also to further explore the specific mechanisms driving daily environmental cardiovascular variability.

Acknowledgments

Supported by NIH grant CA72457.

REFERENCES

- Dettenborn L, James GD, van Berge-Landry H, Valdimarsdottir HB, Montgomery GH, Bovbjerg DH. Heightened cortisol responses to daily stress in working women at familial risk for breast cancer. *Biol Psychol.* 2005; 69:167–179. [PubMed: 15804544]
- Flores JS. Blood pressure variability: A novel and important risk factor. *Can J Cardiol.* 2013; 29:557–563. [PubMed: 23618505]

- Hansen TW, Thijs L, Li Y, Boggia J, Kikuya M, Björklund-Bodegård K, Richart T, Ohkubo T, Jeppesen J, Torp-Pedersen C, Dolan E, Kuznetsova T, Stolarz-Skrzpek K, Tikhonoff V, Malyutina S, Casiglia E, Nikitin Y, Lind L, Sandoya E, Kawecka-Jaszcz K, Imai Y, Wang J, Ibsen H, O'Brien E, Staessen JA. International Database on Ambulatory Blood Pressure in Relation to Cardiovascular Outcomes Investigators. Prognostic value of reading-to-reading blood pressure variability over 24 hours in 8938 subjects from 11 populations. *Hypertension*. 2010; 55:1049–1057. [PubMed: 20212270]
- James, GD. Evaluation of journals, diaries, and indexes of worksite and environmental stress. In: White, WH., editor. *Clinical Hypertension and Vascular Disease: Blood Pressure Monitoring in Cardiovascular Medicine and Therapeutics*. 2nd Edition. Totowa, N.J.: The Humana Press; 2007. p. 39-58.
- James GD. Ambulatory blood pressure variation: allostasis and adaptation. *Autonom Neurosci*. 2013; 177:87–94.
- James, GD.; Bovbjerg, DH. Heightened endocrine responses to daily life stressors in healthy women at familial risk for breast cancer. In: Esposito, A.; Bianchi, V., editors. *Cortisol: Physiology, Regulation and Health Implications*. Hauppauge, NY: Nova Scientific Publishers, Inc.; 2012. p. 49-72.
- James GD, Bovbjerg DH, Montgomery GH. The effects of recumbency and sleep on the blood pressure of women employed outside the home. *Am J Phys Anthropol Suppl*. 2001; 32:86.
- James GD, Sievert LL, Flanagan E. Ambulatory blood pressure and heart rate in relation to hot flash experience among women of menopausal age. *Ann Hum Biol*. 2004; 31:49–58. [PubMed: 14742165]
- Kikuya M, Hozawa A, Ohokubo T, Tsuji I, Michimata M, Matsubara M, Ota M, Nagai K, et al. Prognostic significance of blood pressure and heart rate variabilites: the Ohasama study. *Hypertens*. 2000; 36:901–906.
- Palatini P. Elevated heart rate as a predictor of increased cardiovascular morbidity. *J Hypertens*. 1999; 17:3–10.
- Pickering TG, Harshfield GA, Kleinert HD, Blank S, Laragh JH. Blood pressure during normal daily activities, sleep, and exercise. Comparison of values in normal and hypertensive subjects. *J Am Med Assoc*. 1982; 247:992–996.
- Schwan A, Pavsek K. Change in posture during sleep causes errors in non-invasive automatic blood pressure recordings. *J Hypertens*. 1989; 7(suppl. 6):62–63.
- Silvani A. Physiological sleep-dependent changes in arterial blood pressure: central autonomic commands and baroreflex control. *Clin Exp Pharmacol Physiol*. 2008; 35:987–994. [PubMed: 18565197]
- Tabara Y, Tachibana-Imori R, Yamamoto M, Abe M, Kondo I, Miki T, Kohara K. Hypotension associated with prone body position: a possible overlooked postural hypotension. *Hypertens Res*. 2005; 28:741–746. [PubMed: 16419647]
- Van Berge-Landry H, Bovbjerg DH, James GD. The reproducibility of ethnic differences in the proportional awake-sleep blood pressure decline among women. *Am J Hum Biol*. 2010; 22:325–329. [PubMed: 19844896]
- Verdecchia P, Angeli F, Mazzotta G, Garofoli M, Ramundo E, Gentile G, Ambrosio G, Reboldi G. Day-night dip and early-morning surge in blood pressure in hypertension: prognostic implications. *Hypertension*. 2012; 60(1):34–42. [PubMed: 22585951]
- Zanstra YJ, Johnston DW. Cardiovascular reactivity in real life settings: Measurement, mechanisms and meaning. *Biol Psychol*. 2011; 86:98–105. [PubMed: 20561941]

Table 1

Selected Characteristics of the Study Sample (N=206).

Characteristic	Mean±SD or %
Age (years)	37.6±9.1
Height (m)	1.64±0.74
Weight (kg)	68.0±15.5
BMI (kg/m ²)	25.4±5.7
Ethnicity (% white)	57.6
Married (%)	40.4
w/ Children (%)	43.7
Education (% college graduate)	68.3
Smokers (%)	11.7

Microenvironmental Blood Pressure (mmHg) and Heart Rate (bpm) Mean, Absolute Variation (SD), and Proportional Variation (CV) Comparisons.

Table 2

	Mean			Absolute Variation (SD)			Proportional Variation (CV)		
	Work	Home	Sleep	Work	Home	Sleep	Work	Home	Sleep
Systolic	121±11 ^a	120±11 ^a	107±12	7.6±2.4 ^c	8.0±2.9	8.4±3.3	0.06±0.02 ^d	0.07±0.02 ^d	0.08±0.03
Diastolic	82±10 ^{a,b}	80±11 ^a	66±11	7.2±2.5	7.5±2.8	7.7±3.0	0.09±0.03 ^d	0.10±0.04 ^d	0.12±0.05
HR	79±12 ^a	80±12 ^a	68±11	8.1±3.8 ^a	8.2±3.8 ^a	6.9±3.2	0.10±0.04	0.10±0.05	0.11±0.09

^a = Significantly > Sleep; p<0.001
^b = Significantly > Home; p<0.001
^c = Significantly < Sleep; p<0.01
^d = Significantly < Sleep; p<0.001