The enigma of blood pressure variation

The circulation of blood throughout the body comes from the continuous rhythmic pumping action of the heart. Specifically, a pulsatile flow of blood happens when the blood within the heart is ejected out the left ventricle into the aorta. The pressure exerted during the maximum push when the left ventricle contracts is systolic blood pressure, while diastolic blood pressure is the force exerted during the relaxation and dilatation of the heart, when it refills with blood prior to its next contraction and is the minimum pressure of the blood pulse. Arterial blood pressure is thus defined by two numbers: the maximum (systolic) and minimum (diastolic) pressure of a pulse of blood as it is expelled from the heart during one heartbeat. These are the numbers people recognize from their visit to the doctor's office. Remarkably, because each beat generates pressure, the number of measureable systolic and diastolic pressures over a 24 hour period will be equal to the number of heartbeats which will range from about 100,000 to perhaps 130,000 in an average healthy person.

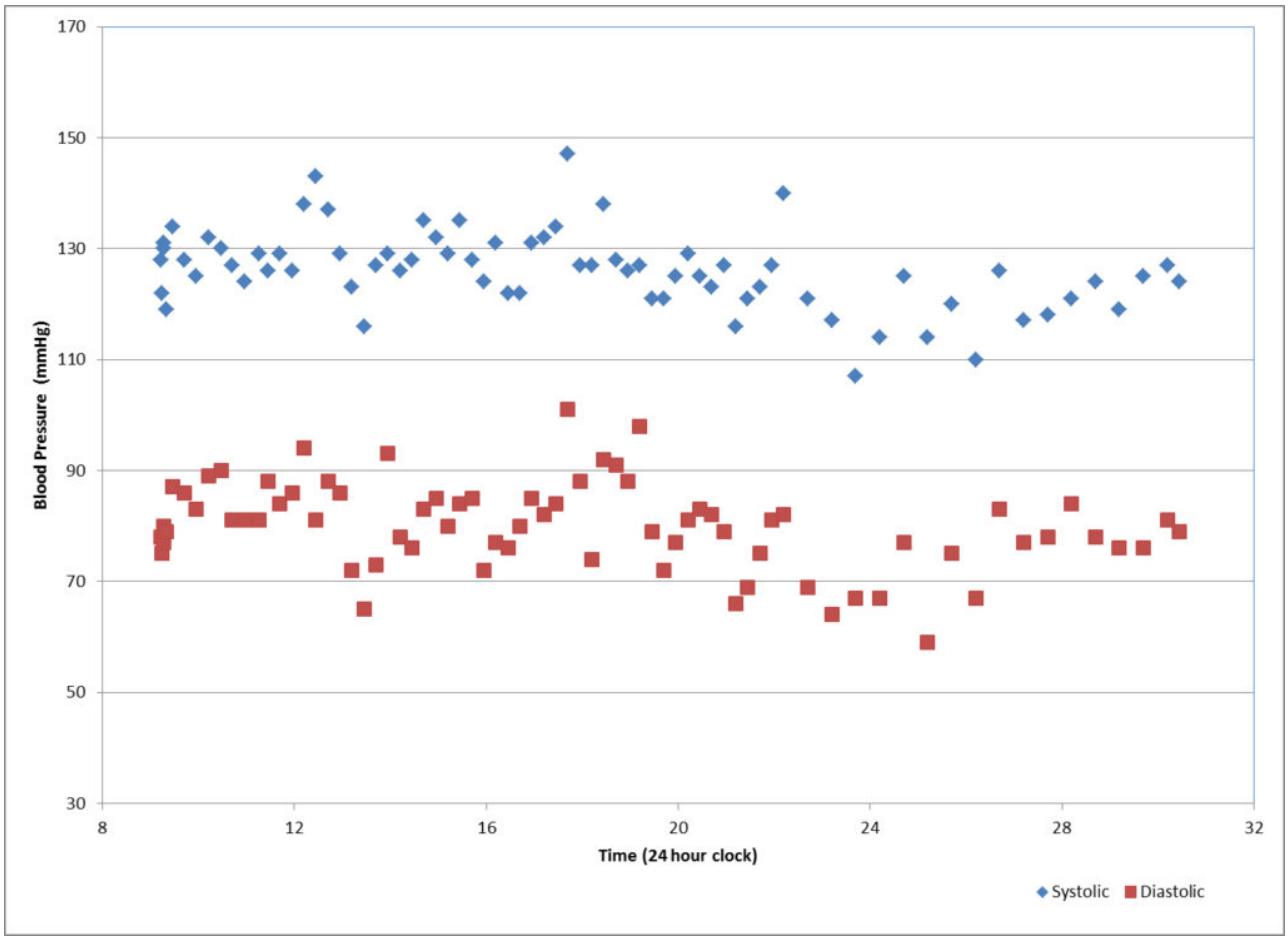

Fig. 1. Variation in Systolic and Diastolic Pressure over a 24 hour period. Pressures were taken with an ambulatory blood pressure monitor every 15 minutes from 8 AM to 10 PM and every 30 minutes from 10 PM to 8 AM the next day.

Blood pressure is an archetypal physiological function that undergoes allostasis, meaning that it is highly variable over time and by circumstance. It is a continuous function that is controlled by neural inputs and the actions of a host of hormones which regulate the volume of fluid in the vascular system, cardiac output, arterial stiffness and renal perfusion and it can also be increased or decreased by injury or inflammation of the vasculature and target organs such as the heart and kidneys.

Variability is a normative property of blood pressure necessary for survival. Blood pressure change is an adaptive process, and circadian blood pressure variation, most notably that related to the biobehavioral changes from waking to sleep reflect adaptive responses to habitual activity and postural variation associated with everyday life processes and sleep. Hence, an atypical event in life such as visiting the physician's office with its unique circumstances can lead to an adaptive accentuated blood pressure response which in turn can result in a misdiagnosis of hypertension. Blood pressure variability is inexorable and relentless; it most likely contributes to morbidity and mortality through the wear and tear that the body experiences due to repeated cycles of allostasis as well as the inefficient turning on or shutting off of the blood pressure regulatory mechanisms. Interestingly, the technology of taking a non-invasive blood pressure measurement using a cuff can create blood pressure variation, first by inducing stress through the squeezing of the arm, and second through the recording of systolic and diastolic pressure from different blood pulses. Statistical methods of expressing circadian variation such as the standard deviation or other summary methods such as comparing average waking and sleep pressure don't capture the allostatic and adaptive properties of blood pressure and thus are not very useful for evaluating the health implications of blood pressure variability. Quantifying the sources and extent of blood pressure variability can be done using natural experimental models and through the evaluation of ecological momentary data (Fig. 1). There are also physiological distinctions between populations related to their biological evolutionary history that likely further affect individual and population differences in circadian blood pressure variability. These distinctions are related to broader genetic adaptations to long-term pervasive environmental stressors such as prolonged cold temperature and poor salt availability. It is very likely that the results of population studies that examine blood pressure variability and its relationship with cardiovascular morbidity and mortality risk are contradictory because the parameters used to assess blood pressure variability do not reflect the actual nature of blood pressure allostasis and adaptation.

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Publication

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