Real World Blood Pressure Variability in Over 56,000 Individuals with Nearly 17 Million Measurements

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Abstract

Background: Visit-to-visit and day-to day blood pressure variability (BPV) are known to be associated with an increased risk of stroke, coronary events, and mortality independent of the mean blood pressure (BP). However, current data were acquired in the setting of clinical trials or registry. We aimed to investigate the real world characteristics of BPV and its association with age, gender, time, and location using the home BP dataset from users of Withings' Wireless Blood Pressure Monitors.

Methods: We included 56,365 participants from US, France, Germany, UK, and other countries who have ≥ 20 BP measurements with the earliest and latest separated by at least 1 month. We computed standard deviation (SD), coefficient of variation (CV), maximum BP, and maximum minus minimum BP difference (MMD) as an intra-individual BPV index.

Results: After excluding outlier (SBP < 50 mmHg or > 300 mmHg), we analyzed 16,904,844 BP measurements data (number of median BP measurements per person: 146, IQR 73-321). BPV index were higher in female compared with male (p<0.001) and increased with age (p<0.001). In addition, there was significant difference according to geographic location (p<0.001). Compared to weekend, weekday BPV index were higher, and this finding was more prominent in female participants (p=0.001). Distribution of maximal SBP showed distinct pattern, higher prevalence during winter season (November ~ February), Monday, and morning (6:00 ~ 10:00 AM) and evening (19:00 ~ 22:00 PM). In multivariate analysis, BPV index were significantly associated with age, gender, geographic location, and mean BP values.

Conclusion: In this study, we showed the characteristics of BPV and its association with other variables and could establish reference values for BPV index from global real world home BP dataset.

Background

Recent data suggested that blood pressure variability (BPV) has an independent influence on the risk of cardiovascular events or mortality (Diaz et al. Hypertension 2014, Muntner et al. Ann Intern Med 2015, Gosmanova et al. J Am Coll Cardiol 2016).

BPV including short-term (over 24 hours), mid-term (day-to-day) and long-term (visit-to-visit) variability is reproducible and not a random phenomenon (Parati et al. Nat Rev Cardiol 2013).

Previous data of BPV were acquired from clinic based or community based cohort study. Thus, there was limitation that those data were not fully representative of the real-world characteristic of BPV. In addition, due to the limitation of study population and geographic location, more general data-set including real-world representative data of blood pressure measurement are required to investigate the relationship between BPV and its clinical outcome.

Real-world data-set using mobile device has advantage over traditional data-set in the volume of data acquisition, thus it is possible to collect multiple data without intervening the usual activity of daily life. In addition, any changes associated with environmental, emotional, or seasonal variation can be detected using mobile device.

Aims of Study

In this study, we tried to investigate the characteristics and the associated factors of BPV using real-world data acquired from wireless blood pressure monitoring device throughout the world. Furthermore, we aimed to provide reference values of BPV according to blood pressure values and age.

Methods & Participants

Participants

From the data-set of active user of Withings' wireless blood pressure monitor, we included a total of 56,365 participants from US, France, Germany, UK, and other countries who have ≥ 20 blood pressure measurements with the earliest and latest separated by at least 1 month.

Data acquisition, management, and definition for analysis

The device automatically saves systolic and diastolic blood pressure data, accurate time of measurement and sends it to network servers. After excluding duplicated values and outlier (SBP < 50 mmHg or > 300 mmHg), we analyzed 16,904,844 systolic blood pressure measurements data (number of median BP measurements per person: 146, IQR 73-321)

Calculation of BPV index

We computed standard deviation (SD), coefficient of variation (CV), maximum BP, and maximum minus minimum BP difference (MMD) as an intra-individual BPV index.[1]

Statistical analysis

We report means (SD) or medians with interquartile ranges for continuous variables and counts with percentages for categorical variables. We analyzed the data using R package (version 3.3.1, https://www.r-project.org/) and SPSS 21.0 (IBM-SPSS Inc., Chicago, Il, USA). All data from the participants were de-identified and analyzed anonymously.

Results

Figure 1. Flow chart of data analysis

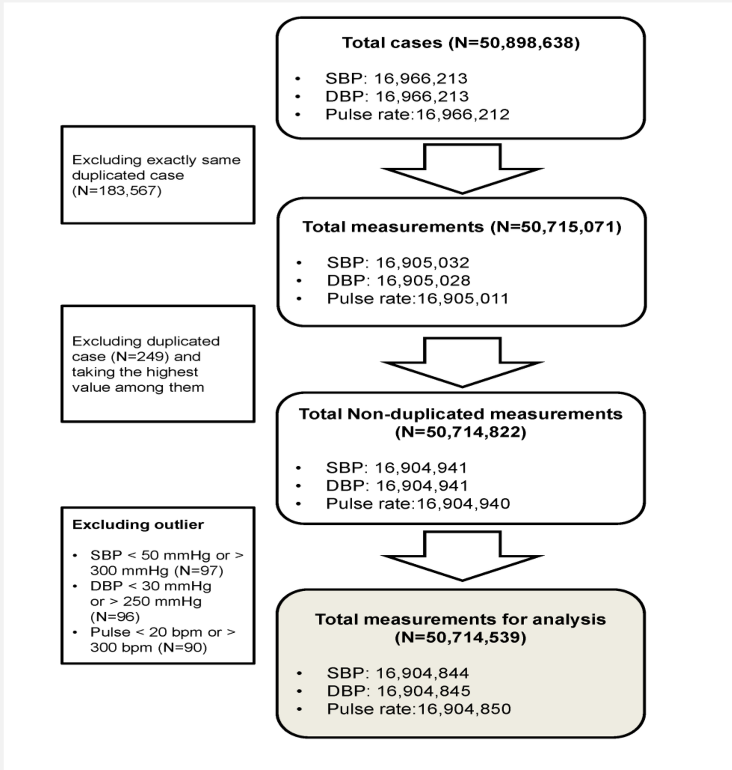


Table 1. Characteristics of study participants

	Number of participants (N=56,365)
Gender	
Male	44,844 (79.6%)
Female	11,521 (20.4%)
Age (year)	
18 ~ 29	928 (1.6%)
30 ~ 39	5,674 (10.1%)
40 ~ 49	13,129 (23.3%)
50 ~ 59	16,552 (29.4%)
60 ~ 69	13,065 (23.2%)
70 ~ 79	5,742 (10.2%)
80 ~ 89	1,181 (2.1%)
90 +	94 (0.2%)
Country	
Canada	2,101 (3.7%)
Switzerland	2,416 (4.3%)
Germany	9,070 (16.1%)
France	3,665 (6.5%)
United Kingdom	2,625 (4.7%)
Italy	1,944 (3.4%)
Japan	1,174 (2.1%)
United State	19,963 (35.4%)
Others*	13,407 (23.8%)

*; Other countries where less than 1000 participants enrolled for this analysis

Figure 2. Distribution of age (A) and gender (B) according to intra-individual coefficient of variation (CV) of SBP (N=56,365)

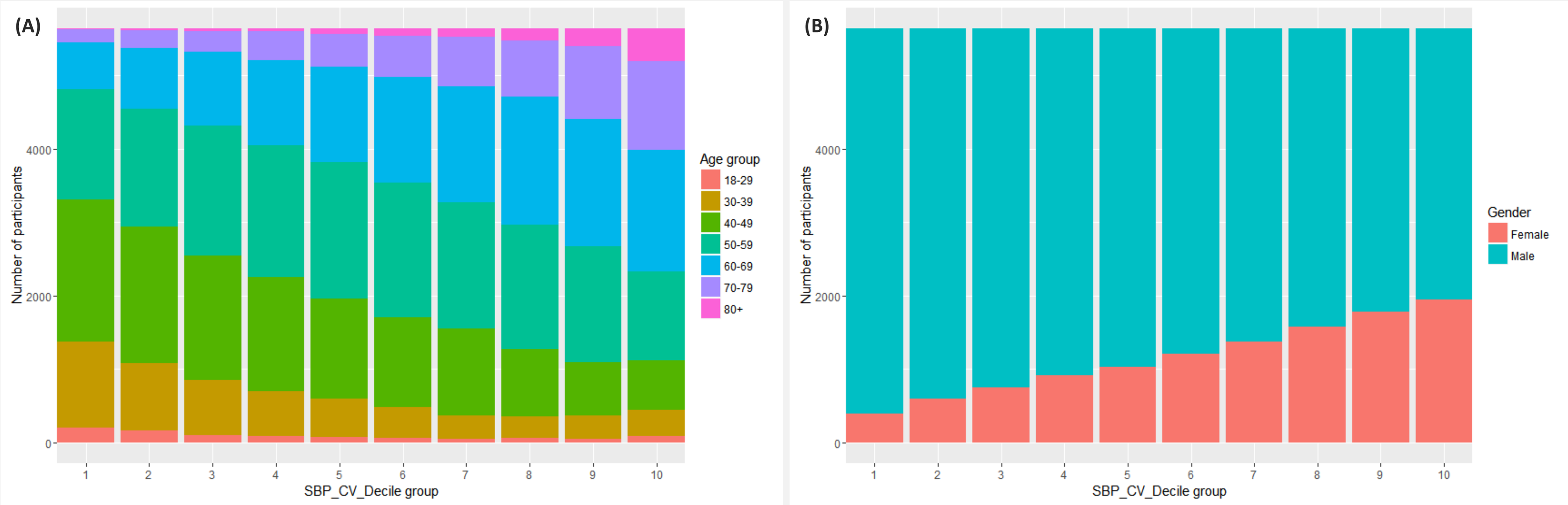
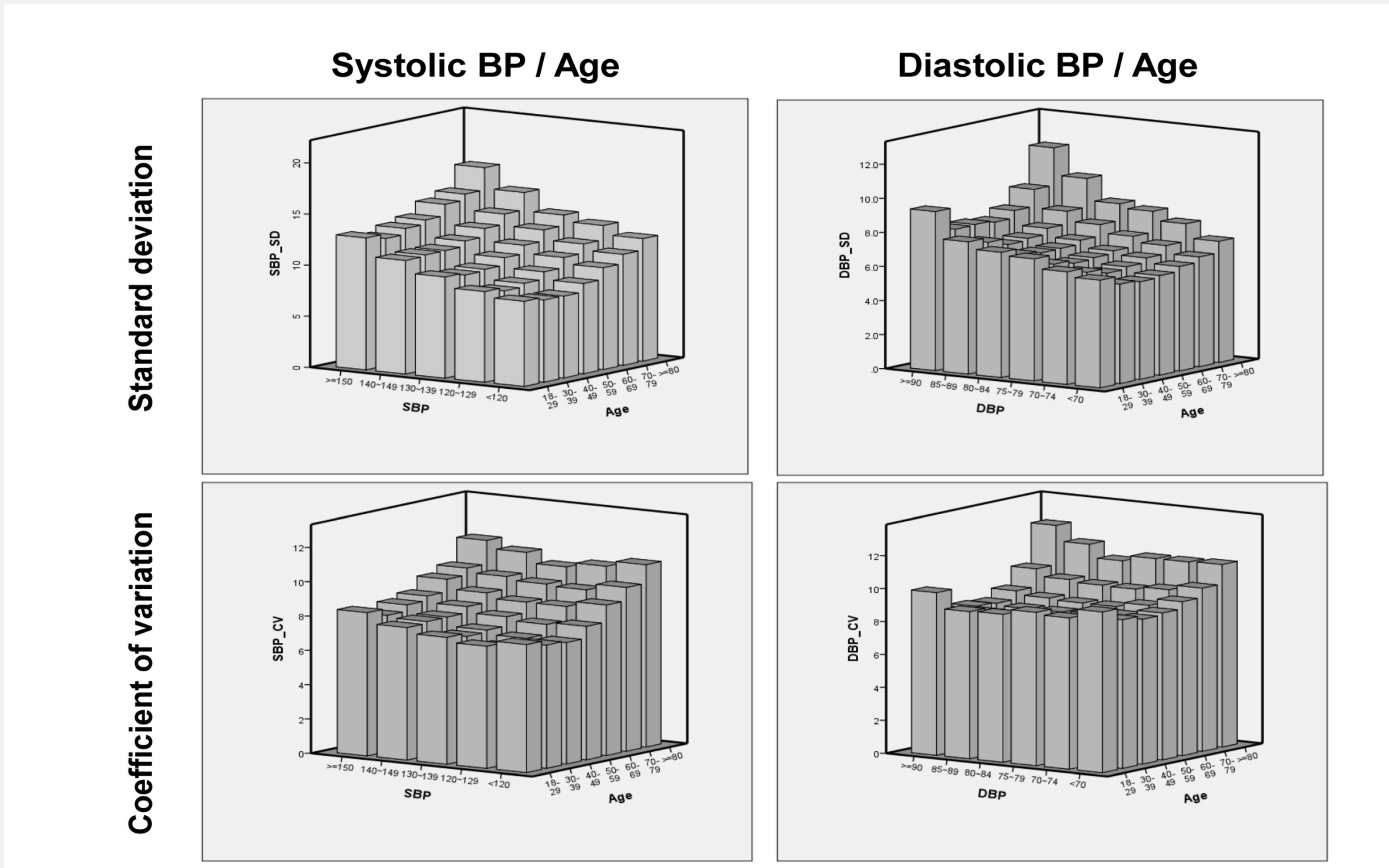


Figure 3. Reference value of intra-individual standard deviation of SBP according to SBP levels and age



* Coefficient of variation : Standard deviation/mean of BP x 100

Figure 4. Relationship between systolic blood pressure and standard deviation of systolic blood pressure according to age

Figure 5. Distribution of maximal systolic blood pressure according to month (A), day of week (B), rounded hour (C)

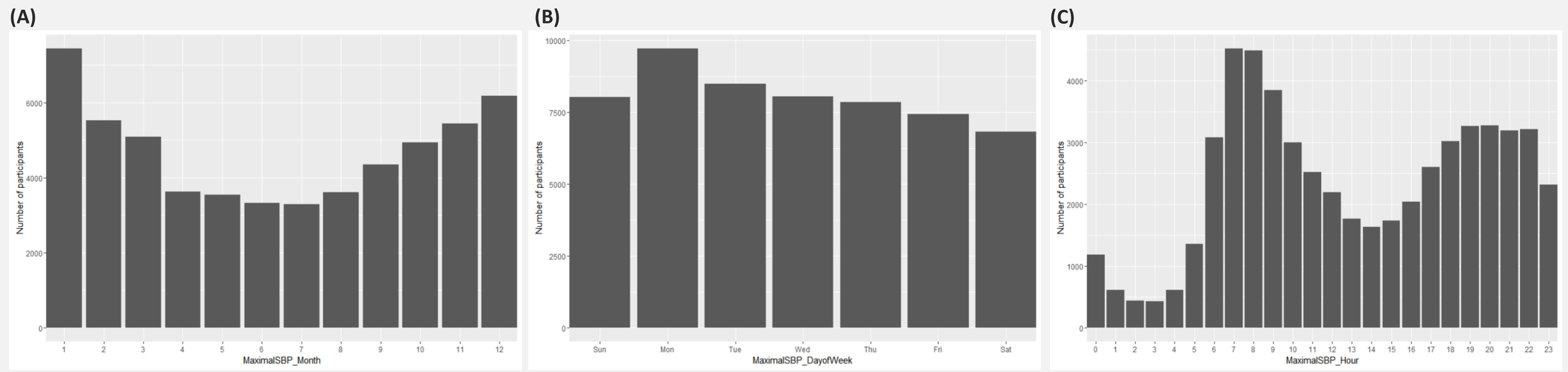


Table 2. Multiple linear regression analysis associated with blood pressure variability (CV of SBP)

	Unstandardized Coefficients (B)	Standard Error	95% Confidence Interval for B		P value
			Lower	Upper	
(Intercept)	4.043	0.1423	3.764	4.322	< 0.001
Female	1.079	0.0236	1.033	1.125	< 0.001
Male	Reference				
Age 80+	2.807	0.0978	2.615	2.998	< 0.001
Age 70 ~ 79	1.846	0.0799	1.690	2.003	< 0.001
Age 60 ~ 69	1.172	0.0761	1.023	1.321	< 0.001
Age 50 ~ 59	0.556	0.0755	0.408	0.704	< 0.001
Age 40 ~ 49	0.032	0.0761	-0.117	0.181	0.677
Age 30 ~ 39	-0.196	0.0791	-0.351	-0.042	0.013
Age 18 ~ 29	Reference				
Country (US)	0.452	0.0511	0.351	0.552	< 0.001
Country (Other)	0.356	0.0524	0.254	0.459	< 0.001
Country (JP)	0.235	0.0815	0.076	0.395	0.004
Country (IT)	0.431	0.0702	0.293	0.568	< 0.001
Country (GB)	-0.157	0.0653	-0.285	-0.029	0.016
Country (FR)	0.159	0.0610	0.039	0.278	0.009
Country (DE)	-0.206	0.0540	-0.312	-0.100	< 0.001
Country (CH)	-0.133	0.0665	-0.263	-0.003	0.045
Country (CA)	Reference				
Mean SBP	0.018	0.0013	0.016	0.021	< 0.001
Mean DBP	0.006	0.0018	0.003	0.010	< 0.001

CA; Canada, CH; Switzerland, DE; Germany, FR; France, GB; United Kingdom, IT; Italy, JP; Japan. SBP; systolic blood pressure, DBP; diastolic blood pressure

Conclusion

We showed the characteristics of BPV and its association with age, sex, and time and seasonal variation. We could also establish reference values for BPV from a global real world home BP dataset that should help with future efforts to identify people who have greater BPV and potentially evaluate therapies that influence it beyond just BP alone, thus further diminishing risks of cardiovascular events or premature mortality.

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