Online supplement

Influence of age on upper-arm cuff blood pressure measurement

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Expanded Methods.

Description of the order of the cuff BP measurements.

Cuff and invasive BP were measured simultaneously in seventeen studies (n=1078). Cuff BP was measured just prior to the invasive BP in seven studies (n=313), whereas invasive BP was measured just prior to cuff BP in five studies (n=204). In one study (n=27), duplicate cuff BP measurements were recorded, then invasive BP, then duplicate cuff BP again with the average of the four cuff values used for analysis. In another study (n=52), an invasive BP was recorded, then cuff BP and then another invasive BP with the average of the duplicate invasive BP recordings used for analysis.

Description of the study quality score used. One point was awarded for each of the five attributes when the highest standard of study quality was met.

1. Type of catheter

- **a)** micromanometer tip: **1 point** OR
- **b)** fluid filled catheter manometer system – description of frequency and damping characteristics: **1 point** OR
- **c)** Fluid filled catheter manometer system – insufficient detail for b): **0 points**

2. Sequence of aortic and brachial BP measurements

- **a)** Simultaneous: **1 point** OR
- **b)** sequential, describing the time between measurements and that no major hemodynamic changes occurred: **1 point** OR
- **c)** sequential, insufficient detail for b): **0 points**

3. Position of catheter in aorta

- **a)** described with sufficient detail to ascertain position (aortic BP was required to be measured in the proximal aorta or aortic arch): **1 point** OR
- **b)** general description: **0 points**

4. Pressure wave capture length

- **a)** > 1 beat of continuously captured data, with a description that the recording was of good quality (i.e period of capture was stable): **1 point** OR
- **b)** 1 beat: **0 points** OR
- **c)** or no description: **0 points**

5. Participant characteristics

- **a)** description of patient inclusion/exclusion criteria (with reference to conditions that may cause hemodynamic instability / difficulty to obtain accurate measurements): **1 point** OR
- **b)** detailed description of the patient clinical characteristics (with reference to conditions that may cause hemodynamic instability / difficulty to obtain accurate measurements): **1 point** OR
- **c)** no, or poor, description of the patient inclusion/exclusion criteria (with reference to conditions that may cause hemodynamic instability / difficulty to obtain accurate measurements): **0 points** OR
- **d)** no or poor description of patient clinical characteristics (with reference to conditions that may cause hemodynamic instability / difficulty to obtain accurate measurements): **0 points**

Online supplement Table S1. Studies included in the cuff versus invasive aortic BP analyses.

Citation	Cuff blood pressure device
1. Aakhus et al,[1] Noninvasive Estimates of Aortic Root Pressures - External Subclavian Arterial Pulse Tracing Calibrated by Oscillometrically Determined Brachial Arterial Pressures. *Clin Physiol.* 1993;13(6):573-586.	UA 751, Takeda Medical Inc
2. Bhatt SD, Hinderliter AL, Stouffer GA.[2] Influence of Sex on the Accuracy of Oscillometric-Derived Blood Pressures. *J Clin Hypertens.* 2011;13(2):112-119.	Omron device
3. Borow KM, Newburger JW.[3] Noninvasive estimation of central aortic pressure using the oscillometric method for analyzing systemic artery pulsatile blood flow: comparative study of indirect systolic, diastolic, and mean brachial artery pressure with simultaneous direct ascending aortic pressure measurements. *Am Heart J.* 1982;103(5):879-886.	Dinamap 845
4. Bos et al,[4] Pseudohypertension and the measurement of blood pressure. *Hypertension.* 1992;20(1):26-31.	Mercury sphygmomanometer
5. Broyd et al, unpublished*	PulseCor R6.5 (POEM2 oscillometric BP [Welch Allyn])
6. Cheng HM, Wang KL, Chen YH, et al.[5] Estimation of central systolic blood pressure using an oscillometric blood pressure monitor. *Hypertens Res.* 2010;33(6):592-599.	VP-2000, Colin corporation
7. Cheng et al, unpublished*	VP-2000, Colin corporation
8. Costello BT, Schultz MG, Black JA, Sharman JE.[6] Evaluation of a brachial cuff and suprasystolic waveform algorithm method to noninvasively derive central blood pressure. *Am J Hypertens.* 2015;28(4):480-486.	Pulsecor R7.0 (Welch Allyn brachial BP)
9. Cremer A, Butlin M, Codjo L, et al.[7] Determination of central blood pressure by a noninvasive method (brachial BP and QKD interval). *J Hypertens.* 2012;30(8):1533-1539.	Diasys Integra II
10. Ding FH, Li Y, Zhang RY, Zhang Q, Wang JG.[8] Comparison of the SphygmoCor and Omron devices in the estimation of pressure amplification against the invasive catheter measurement. *J Hypertens.* 2013;31(1):86-93.	Omron HEM 9000AI
11. Jeon WK, Kim MA, Kim HL, et al.[9] Association between aortic knob width and invasively	Mennen Medical oscillometric monitor

measured aortic pulse pressure. Blood Press Monit. 2018; 23(3): 121-6.	
12. Laugesen E, Rossen NB, Peters CD, et al.[10] Assessment of central blood pressure in patients with type 2 diabetes: a comparison between SphygmoCor and invasively measured values. *Am J Hypertens.* 2014;27(2):169-176.	Riester Champion N automatic blood pressure monitor
13. Lin MM, Cheng HM, Sung SH, et al.[11] Estimation of central aortic systolic pressure from the second systolic peak of the peripheral upper limb pulse depends on central aortic pressure waveform morphology. *J Hypertens.* 2012;30(3):581-586.	WatchBP Office, Microlife
14. Nagle et al,[12] Comparisons of direct and indirect blood pressure with pressure-flow dynamics during exercise. *J Appl Physiol.* 1966;21(1):317-320.	Mercury sphygmomanometer
15. Nakagomi A, Okada S, Shoji T, Kobayashi Y.[13] Aortic pulsatility assessed by an oscillometric method is associated with coronary atherosclerosis in elderly people. *Blood Press.* 2016:1-8.	Mobil-o-graph, IEM
16. Ohte N, Saeki T, Miyabe H, et al.[14] Relationship between blood pressure obtained from the upper arm with a cuff-type sphygmomanometer and central blood pressure measured with a catheter-tipped micromanometer. *Heart Vessels.* 2007;22(6):410-415.	BP-8800, Omron Colin
17. Ott C, Haetinger S, Schneider MP, Pauschinger M, Schmieder RE.[15] Comparison of two noninvasive devices for measurement of central systolic blood pressure with invasive measurement during cardiac catheterization. *J Clin Hypertens (Greenwich).* 2012;14(9):575-579.	Dinamap Pro 100 V2
18. Park CM, Korolkova O, Davies JE, et al.[16] Arterial pressure: agreement between a brachial cuff-based device and radial tonometry. *J Hypertens.* 2014;32(4):865-872.	PulseCor R6.5 (POEM2 oscillometric BP [Welch Allyn])
19. Park et al, unpublished*	PulseCor R6.5 (POEM2 oscillometric BP [Welch Allyn])
20. Pereira T, Maldonado J, Coutinho R, et al.[17] Invasive validation of the Complior Analyse in the assessment of central artery pressure curves: a methodological study. *Blood Press Monit.* 2014;19(5):280-287.	Colson MAM BP 3AA1-2
21. Picone et al, unpublished*	Sphygmocor Xcel (oscillometric BP Suntech Advantage NIBP)
22. Pucci G, Cheriyan J, Hubsch A, et al.[18] Evaluation of the Vicorder, a novel cuff-based device for the noninvasive estimation of central blood pressure. *J Hypertens.* 2013;31(1):77-85.	Vicorder

23. Pucci et al, unpublished*	Omron HEM 9000AI
24. Rossen NB, Laugesen E, Peters CD, et al.[19] Invasive validation of arteriograph estimates of central blood pressure in patients with type 2 diabetes. *Am J Hypertens.* 2014;27(5):674-679.	Arteriograph
25. Sueta D, Yamamoto E, Tanaka T, et al.[20] The accuracy of central blood pressure waveform by novel mathematical transformation of non-invasive measurement. *Int J Cardiol.* 2015;189:244-246.	Pasesa AVE-1500 (Shisei Datum)
26. Smulyan H, Siddiqui DS, Carlson RJ, London GM, Safar ME.[21] Clinical utility of aortic pulses and pressures calculated from applanated radial-artery pulses. *Hypertension.* 2003;42(2):150-155.	Colin Medical Instruments (oscillometric)
27. Smulyan H, Sheehe PR, Safar ME.[22] A preliminary evaluation of the mean arterial pressure as measured by cuff oscillometry. *Am J Hypertens.* 2008;21(2):166-171.	Colin Medical Instruments (oscillometric)
28. Smulyan H, Mukherjee R, Sheehe PR, Safar ME.[23] Cuff and aortic pressure differences during dobutamine infusion: a study of the effects of systolic blood pressure amplification. *Am Heart J.* 2010;159(3):399-405.	Colin Medical Instruments (oscillometric)
29. Takazawa K, Kobayashi H, Shindo N, Tanaka N, Yamashina A.[24] Relationship between radial and central arterial pulse wave and evaluation of central aortic pressure using the radial arterial pulse wave. *Hypertens Res.* 2007;30(3):219-228.	TM2740; Colin Medical Technology Co, Komaki, Japan)
30. Takazawa K, Kobayashi H, Kojima I, et al.[25] Estimation of central aortic systolic pressure using late systolic inflection of radial artery pulse and its application to vasodilator therapy. *J Hypertens.* 2012;30(5):908-916.	Omron HEM-9000AI
31. Weber T, Wassertheurer S, Rammer M, et al.[26] Validation of a brachial cuff-based method for estimating central systolic blood pressure. *Hypertension.* 2011;58(5):825-832.	Mobil-o-graph, IEM

*Unpublished study details are reported in Online Appendix 1 of Picone et al, J Am Coll Cardiol, 2017; 70(5):572-86.

Online supplement Table S2. Studies included in the cuff versus invasive brachial BP sensitivity analyses.

Citation	Cuff blood pressure device
1. Berliner K, Yildiz M, Garnier B, Lee DH, Fujiy H.[27] Blood Pressure Measurements in Obese Persons - Comparison of Intra-Arterial and Auscultatory Measurements. *Am J Cardiol.* 1961;8(1):10-	Auscultation (Baumanometer)
2. Bos et al,[4] Pseudohypertension and the measurement of blood pressure. *Hypertension.* 1992;20(1):26-31.	Mercury sphygmomanometer (Groups B, C). Hawksley Random Zero sphygmomanometer (Group D)
3. Cheng HM, Wang KL, Chen YH, et al.[5] Estimation of central systolic blood pressure using an oscillometric blood pressure monitor. *Hypertens Res.* 2010;33(6):592-599.	VP-2000 Colin Corporation
4. Cheng et al, unpublished (methods identical to study 3.)	VP-2000 Colin Corporation
5. Ding FH, Li Y, Zhang RY, Zhang Q, Wang JG.[8] Comparison of the SphygmoCor and Omron devices in the estimation of pressure amplification against the invasive catheter measurement. *J Hypertens.* 2013;31(1):86-93.	Omron HEM 9000AI
6. Lin MM, Cheng HM, Sung SH, et al.[11] Estimation of central aortic systolic pressure from the second systolic peak of the peripheral upper limb pulse depends on central aortic pressure waveform morphology. *J Hypertens.* 2012;30(3):581-586.	WatchBP Office, Microlife
7. Melamed R, Johnson K, Pothen B, Sprenkle MD, Johnson PJ.[28] Invasive blood pressure monitoring systems in the ICU: influence of the blood-conserving device on the dynamic response characteristics and agreement with noninvasive measurements. *Blood Press Monit.* 2012;17(5):179-183.	Oscillometric device
8. Muecke S, Bersten A, Plummer J.[29] The mean machine; accurate non-invasive blood pressure measurement in the critically ill patient. *J Clin Monit Comput.* 2009;23(5):283-297.	Oscar2
9. Omboni S, Parati G, Groppelli A, Ulian L, Mancia G.[30] Performance of the AM-5600 blood pressure monitor: comparison with ambulatory intra-arterial	

pressure. *J Appl Physiol (1985).* 1997;82(2):698-703.	AM-5600, Advanced Medical Products
10. Picone DS, Schultz MG, Peng X, et al.[31] Discovery of New Blood Pressure Phenotypes and Relation to Accuracy of Cuff Devices Used in Daily Clinical Practice. Hypertension. 2018;71(6):1239-47.	Sphygmocor Xcel (oscillometric BP Suntech Advantage NIBP)
11. Pucci et al, unpublished*	Omron HEM-9000AI
12. Raftery EB, Ward AP.[32] The indirect method of recording blood pressure. *Cardiovasc Res.* 1968;2(2):210-218.	London School of Hygiene mercury sphygmomanometer

*Unpublished study details are reported in Online Appendix 1 of Picone et al, J Am Coll Cardiol, 2017; 70(5):572-86.

Online supplement Table S3. Cuff blood pressure compared with invasive aortic systolic, diastolic and pulse pressure differences across decades of age.

	Difference	95% confidence interval	p-value
Cuff – invasive aortic systolic blood pressure			
40 to 49 years	3.4	0.5 to 6.3	<0.0001
50 to 59 years	1.2	-1.3 to 3.7	
60 to 69 years	-0.6	-3.1 to 1.8	
70 to 79 years	-2.7	-5.2 to -0.2	
80 to 89 years	-3.7	-7.0 to -0.4	
Cuff – invasive aortic diastolic blood pressure			
40 to 49 years	3.8	1.6 to 6.1	<0.0001
50 to 59 years	5.4	3.4 to 7.4	
60 to 69 years	6.1	4.1 to 8.0	
70 to 79 years	7.9	5.9 to 10.0	
80 to 89 years	9.9	7.4 to 12.5	
Cuff – invasive aortic pulse pressure			
40 to 49 years	-0.4	-3.6 to 2.7	<0.0001
50 to 59 years	-4.2	-7.0 to-1.4	
60 to 69 years	-6.7	-9.4 to-4.0	
70 to 79 years	-10.7	-13.4 to-7.9	
80 to 89 years	-13.6	-17.2 to-10.1	

The ‘difference’ column is the marginal effects of the mean calculated for cuff minus invasive aortic BP at each age decade. The number of subjects in each age decade is as follows: 40 to 49 years, n=168; 50 to 59 years, n=403; 60 to 69 years, n=550; 70 to 79 years, n=447; 80 to 89 years, n=106. Units for all BP data are mm Hg.

Online supplement Table S4. Cuff blood pressure compared with invasive aortic systolic, diastolic and pulse pressure differences across decades of age and adjusted for sex.

	Estimate	95% confidence interval	p-value
Cuff – invasive aortic systolic blood pressure			
Age category	-1.7	-2.3 to -1.2	<0.0001
Sex	4.8	3.4 to 6.1	<0.0001
Cuff – invasive aortic diastolic blood pressure			
Age category	1.5	1.05 to 1.9	<0.0001
Sex	1.9	0.9 to 2.9	0.00020
Cuff – invasive aortic pulse pressure			
Age category	-3.2	-3.8 to -2.6	<0.0001
Sex	2.9	1.5 to 4.2	<0.0001

Linear mixed modelling was used to account for participant clustering within individual studies. The age category refers to subjects grouped according to the following age decades: 40 to 49 years, n=166; 50 to 59 years, n=398; 60 to 69 years, n=537; 70 to 79 years, n=440; 80 to 89 years, n=106. There was no interaction between the age category and sex.

Online supplement Table S5. Cuff blood pressure compared with invasive aortic systolic, diastolic and pulse pressure differences across decades of age, adjusted for mean arterial pressure, heart rate and body mass index.

	Estimate	95% confidence interval	p-value
Cuff – invasive aortic systolic blood pressure			
Age category	-1.4	-2.0 to -0.8	<0.0001
Invasive mean arterial pressure	-0.40	-0.44 to -0.36	<0.0001
Heart rate	0.15	0.10 to 0.20	<0.0001
Body mass index	0.18	0.055 to 0.31	0.0051
Cuff – invasive aortic diastolic blood pressure			
Age category	1.6	1.1 to 2.1	<0.0001
Invasive mean arterial pressure	-0.13	-0.16 to -0.092	<0.0001
Heart rate	-0.029	-0.071 to 0.013	0.18
Body mass index	-0.097	-0.20 to 0.0095	0.075
Cuff – invasive aortic pulse pressure			
Age category	-3.0	-3.6 to -2.3	<0.0001
Invasive mean arterial pressure	-0.28	-0.32 to -0.23	<0.0001
Heart rate	0.18	0.13 to 0.24	<0.0001
Body mass index	0.28	0.14 to 0.42	<0.0001

Linear mixed modelling was used to account for participant clustering within individual studies. The age category refers to subjects grouped according to the following age decades: 40 to 49 years, n=150; 50 to 59 years, n=350; 60 to 69 years, n=443; 70 to 79 years, n=355; 80 to 89 years, n=84.

Online supplement Table S6. Sample characteristics across each decade of age for the cuff and invasive brachial blood pressure measurements.

	40 to 49 years (n=71)	**50 to 59 years (n=141)**	**60 to 69 years (n=159)**	**70 to 79 years (n=118)**	**80 to 89 years (n=31)**
Subject characteristics					
Age, years	45.4±3	54.8±3	64.0 [61.0 to 66.0]	74.6±3	81 [80.0 to 82.5]
Female sex, %*	21 (27)	36 (32)	47 (37)	29 (26)	1 (4)
Height, cm†	166.5±9.6	165.2±9.1	165.6±10.5	164.7±9.8	164.4±6.7
Weight, kg‡	82.3±20.6	81.0±21.5	79.4±17.4	72.6±14.8	67.3±11.5
Body mass index, kg/m^2§	29.7±7.3	29.7±7.6	28.9±6.0	26.7±5.3	24.9±3.6
Heart rate, beats/min ‖	69±13	67±11	68±12	66±12	63±9
Blood pressure					
Cuff systolic blood pressure	143±38	138±26	147±30	149±28	150±27
Cuff diastolic blood pressure	85±21	82±15	78±16	78±13	75±13
Cuff pulse pressure	58±20	56±17	69±22	71±22	75±25
Invasive brachial systolic blood pressure	145±32	143±24	153±30	156±27	157±27
Invasive brachial diastolic blood pressure	80±18	76±14	73±15	71±13	66±11
Invasive brachial pulse pressure	65±18	67±17	80±22	84±21	91±25

Data are mean±standard deviation or median [interquartile range]. All blood pressure units are mm Hg. *n=433; †n=477; ‡n=481; §n=477; ‖n=364.

Online supplement Table S7. Unadjusted data for cuff blood pressure compared with invasive brachial systolic, diastolic and pulse pressure differences across 10-year age groups.

Decade of age	n	Difference	95% confidence interval	p-value (trend)
Cuff – invasive brachial systolic blood pressure				
40 to 49 years	71	-4.2	-8.8 to 0.3	0.025
50 to 59 years	141	-7.1	-11.3 to -2.9	
60 to 69 years	159	-7.5	-11.7 to -3.4	
70 to 79 years	118	-8.1	-12.4 to -3.8	
80 to 89 years	31	-9.5	-15.1 to -3.9	
Cuff – invasive brachial diastolic blood pressure				
40 to 49 years	71	4.4	1.3 to 7.4	0.015
50 to 59 years	141	5.0	2.3 to 7.8	
60 to 69 years	159	4.6	1.9 to 7.3	
70 to 79 years	118	6.2	3.4 to 9.0	
80 to 89 years	31	9.3	5.6 to 13.1	
Cuff – invasive brachial pulse pressure				
40 to 49 years	71	-8.6	-12.9 to -4.2	<0.0001
50 to 59 years	141	-12.1	-16.1 to -8.1	
60 to 69 years	159	-12.2	-16.1 to -8.2	
70 to 79 years	118	-14.3	-18.4 to -10.2	
80 to 89 years	31	-18.8	-24.2 to -13.5	

The ‘difference’ column is the marginal effects of the mean calculated for cuff minus invasive brachial BP at each age group. Units for all BP data are mm Hg.

Online supplement Table S8. Cuff blood pressure compared with invasive brachial systolic, diastolic and pulse pressure differences across decades of age and adjusted for sex.

	Estimate	95% confidence interval	p-value
Cuff – invasive aortic systolic blood pressure			
Age category	-0.58	-1.5 to 0.3	0.20
Sex	0.41	-1.7 to 2.6	0.71
Cuff – invasive aortic diastolic blood pressure			
Age category	1.1	0.45 to 1.7	0.00068
Sex	1.3	-0.22 to 2.8	0.096
Cuff – invasive aortic pulse pressure			
Age category	-1.6	-2.5 to -0.67	0.0006
Sex	-0.87	-3.1 to 1.3	0.44

Linear mixed modelling was used to account for participant clustering within individual studies. The age category refers to subjects grouped according to the following age decades: 40 to 49 years, n=56; 50 to 59 years, n=111; 60 to 69 years, n=128; 70 to 79 years, n=110; 80 to 89 years, n=28. There was no interaction between the age category and sex.

Online supplement Table S9. Cuff blood pressure compared with invasive brachial systolic, diastolic and pulse pressure differences across decades of age, adjusted for mean arterial pressure, heart rate and body mass index.

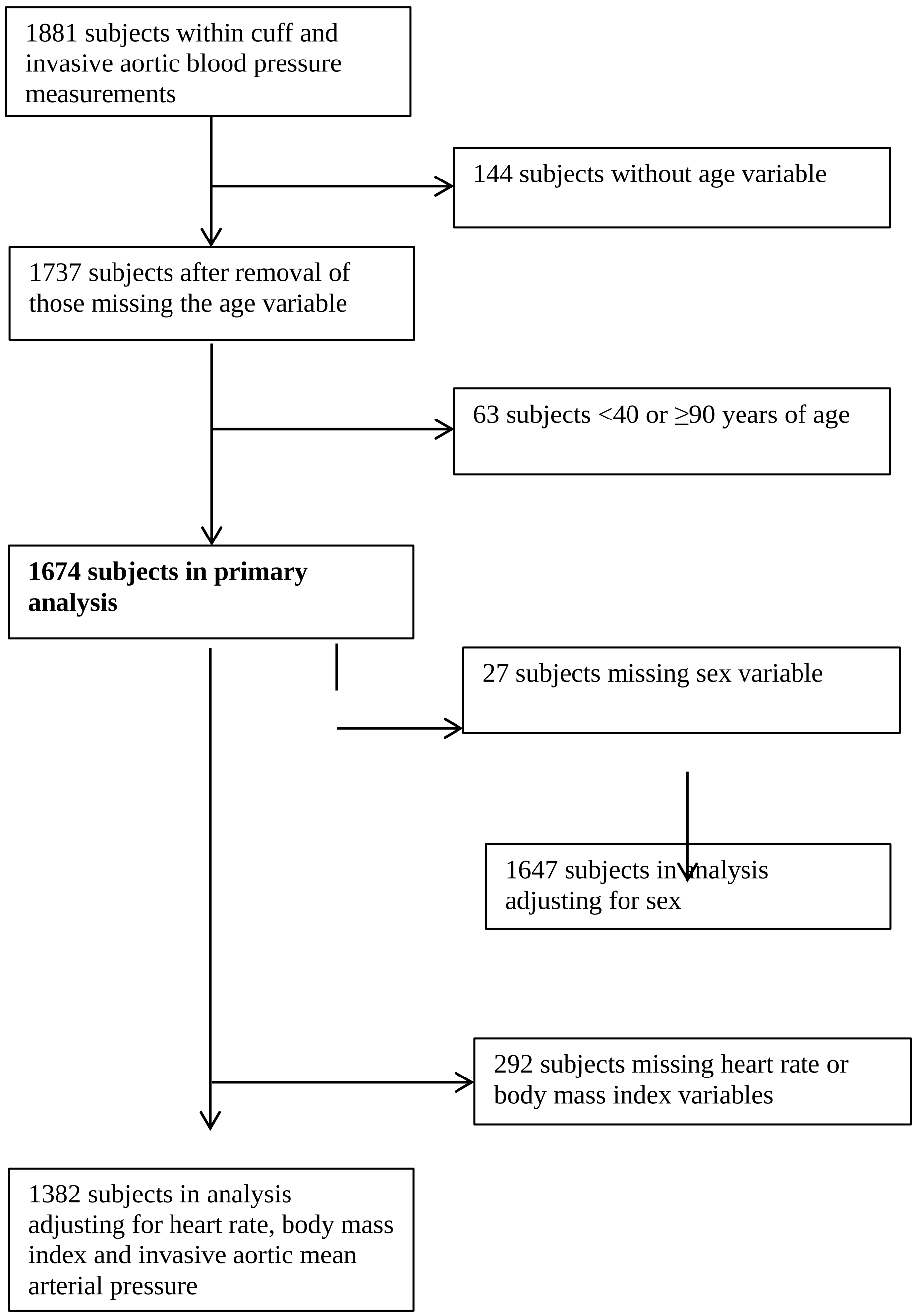
	Estimate	95% confidence interval	p-value
Cuff – invasive brachial systolic blood pressure			
Age category	-0.48	-1.5 to 0.53	0.35
Invasive mean arterial pressure	-0.33	-0.42 to -0.24	<0.0001
Heart rate	0.022	-0.069 to 0.11	0.63
Body mass index	0.077	-0.17 to 0.33	0.55
Cuff – invasive brachial diastolic blood pressure			
Age category	1.2	0.47 to 1.96	0.0016
Invasive mean arterial pressure	-0.030	-0.097 to 0.034	0.37
Heart rate	0.036	-0.032 to 0.010	0.30
Body mass index	-0.29	-0.47 to -0.095	0.0030
Cuff – invasive brachial pulse pressure			
Age category	-1.7	-2.7 to -0.69	0.0011
Invasive mean arterial pressure	-0.30	-0.38 to -0.21	<0.0001
Heart rate	-0.013	-0.10 to 0.078	0.78
Body mass index	0.35	0.096 to 0.60	0.0064

Linear mixed modelling was used to account for participant clustering within individual studies. The age category refers to subjects grouped according to the following age decades: 40 to 49 years, n=40; 50 to 59 years, n=86; 60 to 69 years, n=106; 70 to 79 years, n=79; 80 to 89 years, n=21.

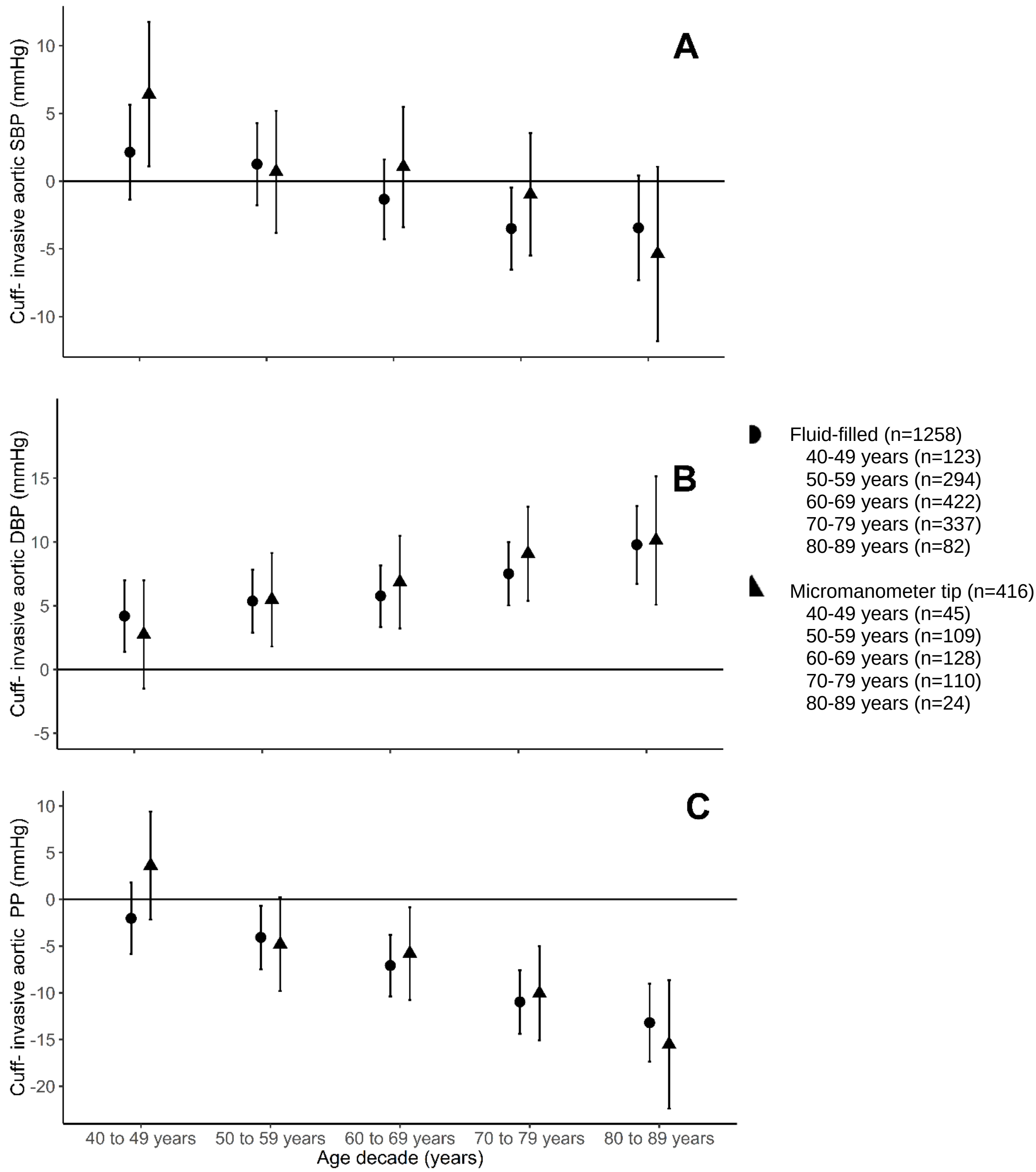
Online supplement Table S10. Influence of age on cuff blood pressure (BP) compared with invasive aortic BP when adjusted for the difference in invasive brachial and invasive aortic systolic, diastolic or pulse pressure (BP amplification).

	Cuff-aortic SBP	Cuff-aortic DBP	Cuff-aortic PP
Age	-1.1 [-2.1 to -0.2] P=0.018	1.3 [0.56 to 2.0] P=0.00043	-2.5 [-3.4 to -1.5] P<0.0001
Invasive brachial – invasive aortic blood pressure	0.47 [0.35 to 0.59] P<0.0001	0.68 [0.49 to 0.88] P<0.0001	0.42 [0.29 to 0.54] P<0.0001

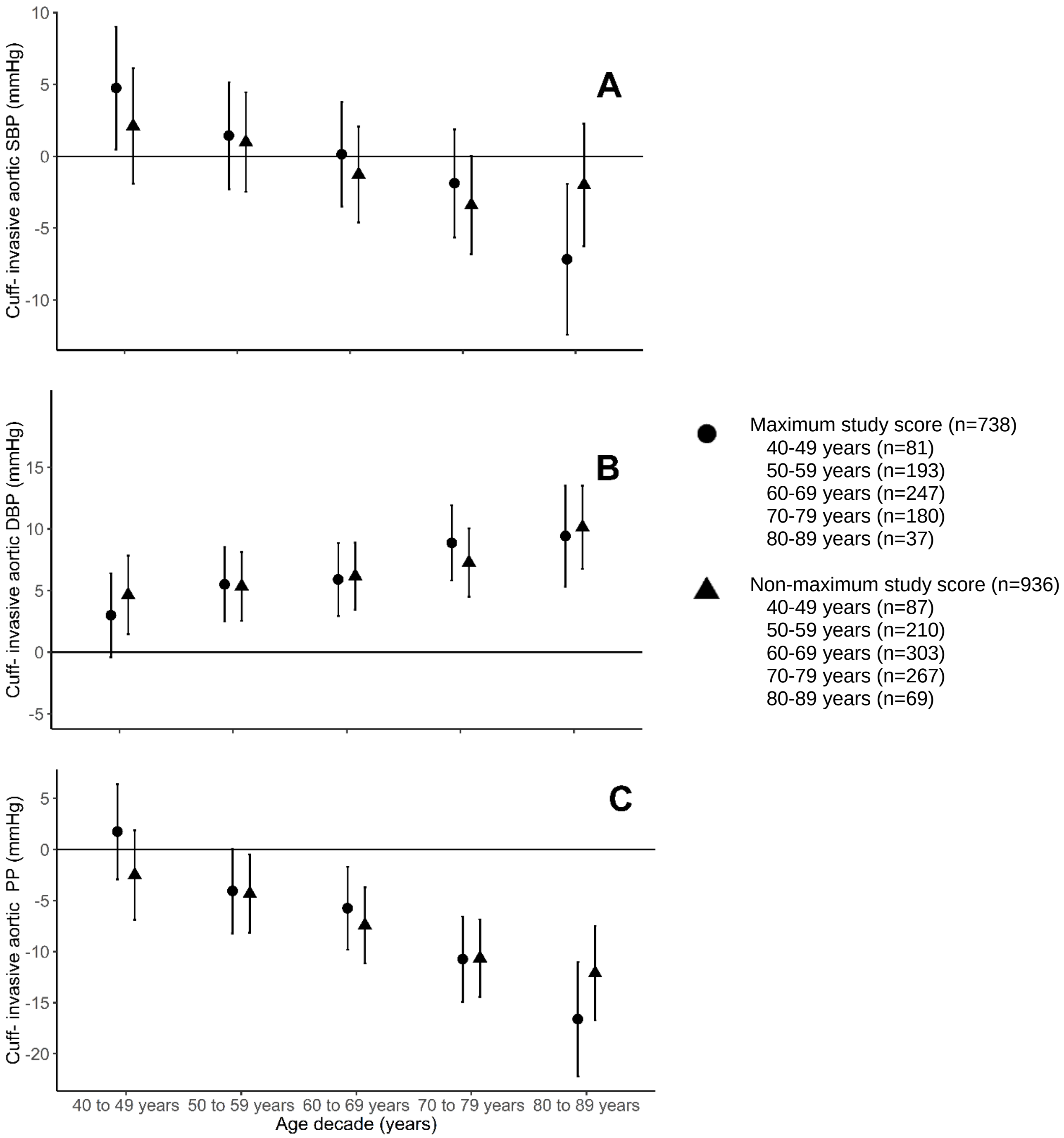
Data are estimate [95% confidence interval] and calculated using linear mixed modelling. SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure.



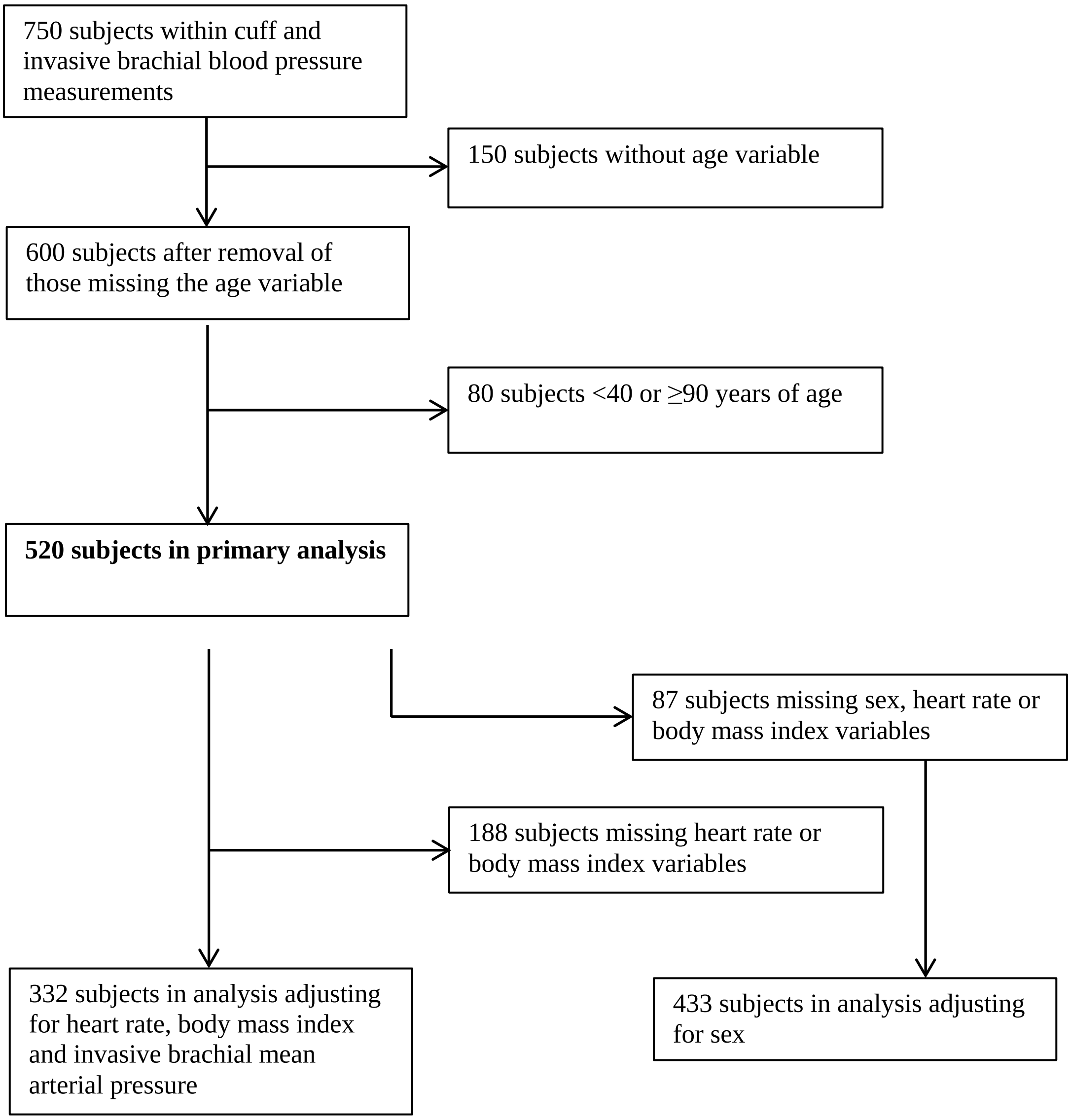
Online supplement Figure S1. Flow of subjects according to the study inclusion criteria from the database of cuff and invasive aortic blood pressure measurements.



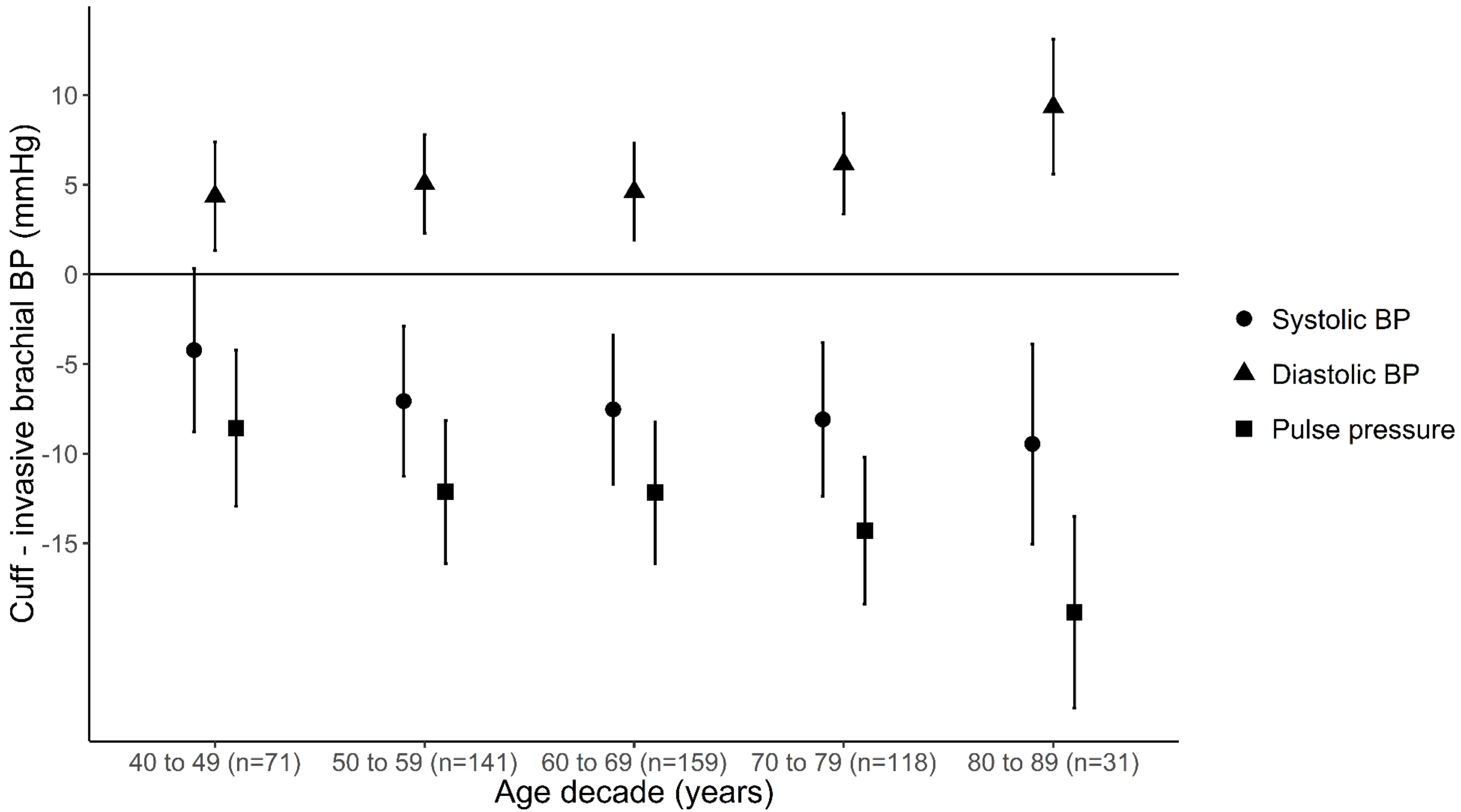
Online supplement Figure S2. Cuff blood pressure (BP) compared with invasive aortic systolic (SBP; A), diastolic (DBP; B) and pulse pressure (PP; C) measurements (y-axis) stratified by the type of catheter (fluid-filled or micromanometer tip) across decades of age (x-axis). Data are mean difference and 95% confidence interval (error bars). The number of subjects in each age and catheter type grouping is shown in the table on the middle right of the figure. Data above the solid horizontal zero line indicates cuff BP is higher than invasive aortic BP and vice versa below the zero line.



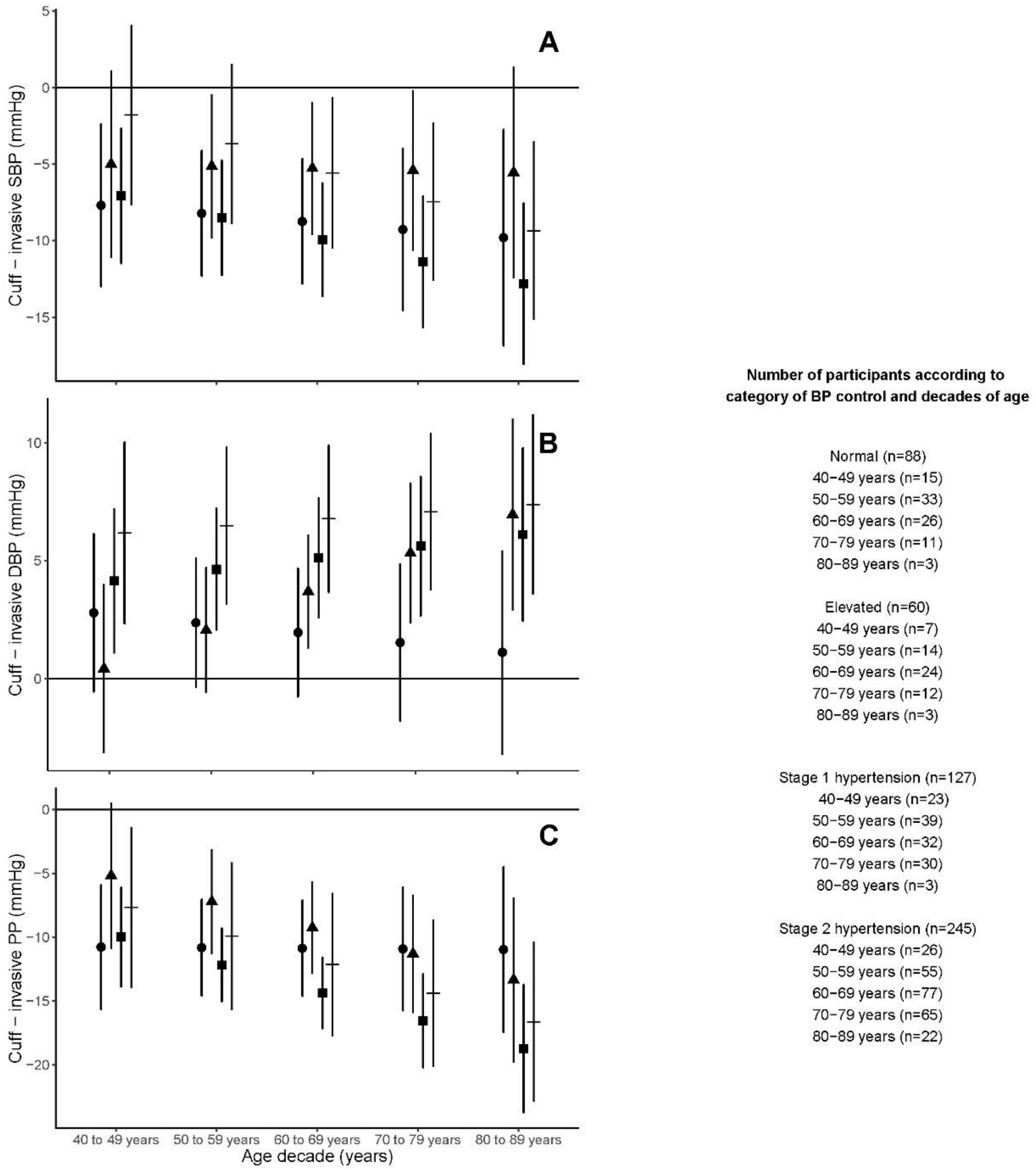
Online supplement Figure S3. Cuff blood pressure (BP) compared with invasive aortic systolic (SBP; A), diastolic (DBP; B) and pulse pressure (PP; C) measurements (y-axis) stratified by the study quality score (maximum or non-maximum score) across ten-year age groups (x-axis). Data are mean difference and 95% confidence interval (error bars). The number of subjects in each age and study quality score grouping is shown in the table on the middle right of the figure. Data above the solid horizontal zero line indicates cuff BP is higher than invasive aortic BP and vice versa below the zero line.



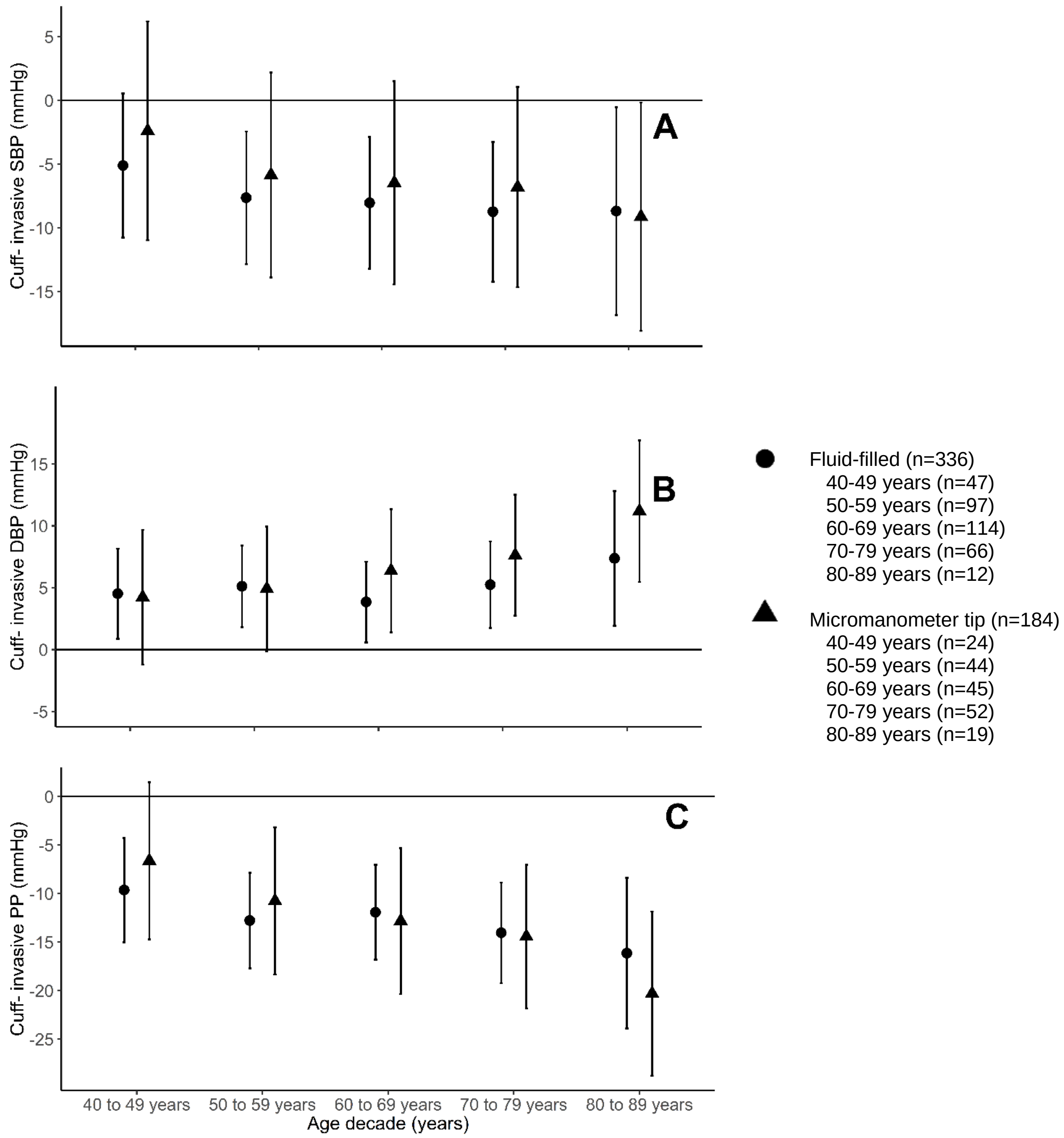
Online supplement Figure S4. Flow of subjects according to the study inclusion criteria from the database of cuff and invasive brachial blood pressure measurements.



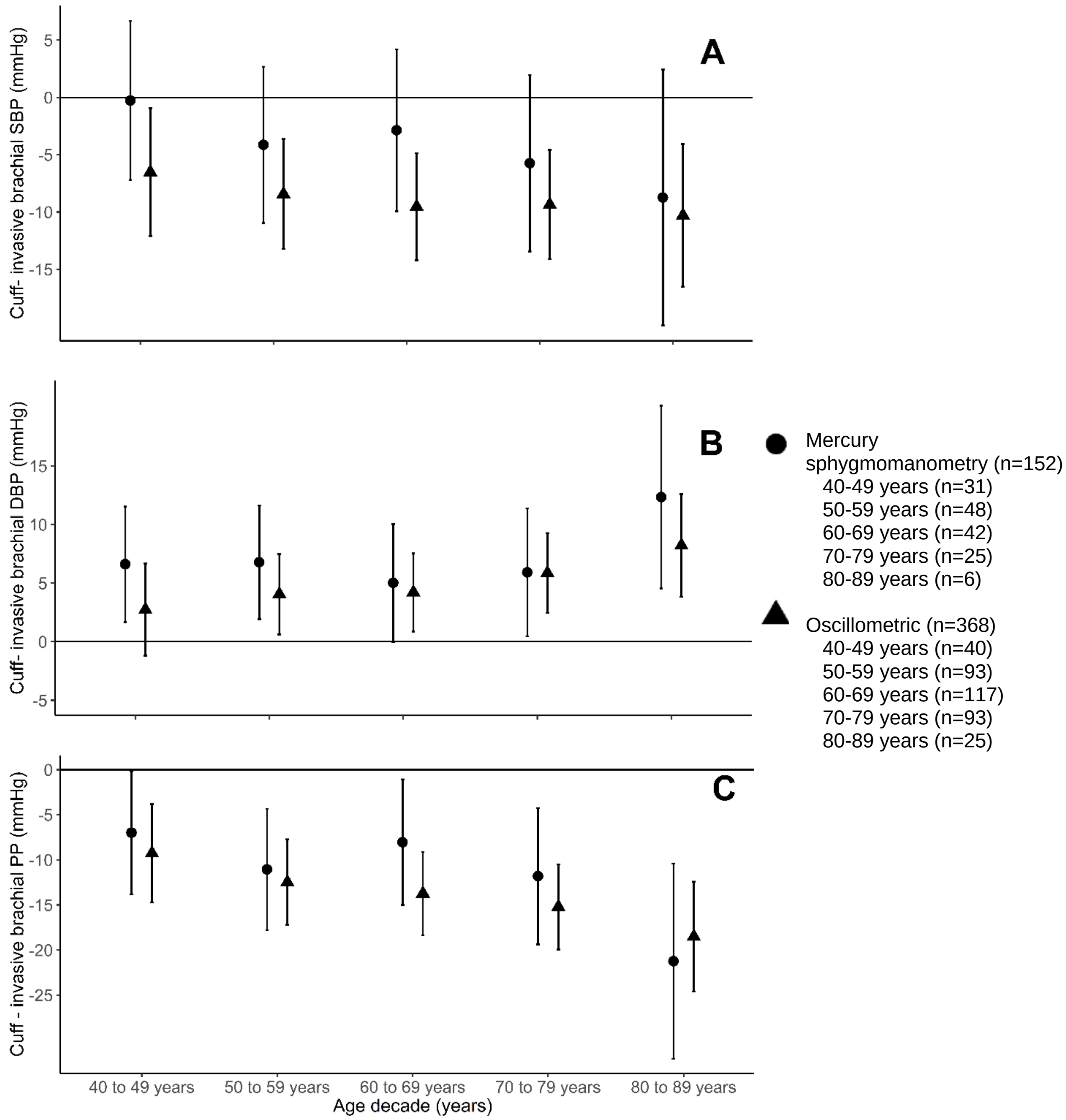
Online supplement Figure S5. Cuff blood pressure (BP) compared with invasive brachial systolic BP (red), diastolic BP (green) and pulse pressure (blue) measurements across age decades. Data are mean difference and 95% confidence interval (error bars). Data above the solid horizontal zero line indicates cuff BP is higher than invasive brachial BP and vice versa below the zero line. The trend for age related difference in cuff BP compared with invasive aortic BP was significant for each of BP variable, p=0.025 systolic BP, p=0.015 diastolic BP and p<0.0001 pulse pressure.



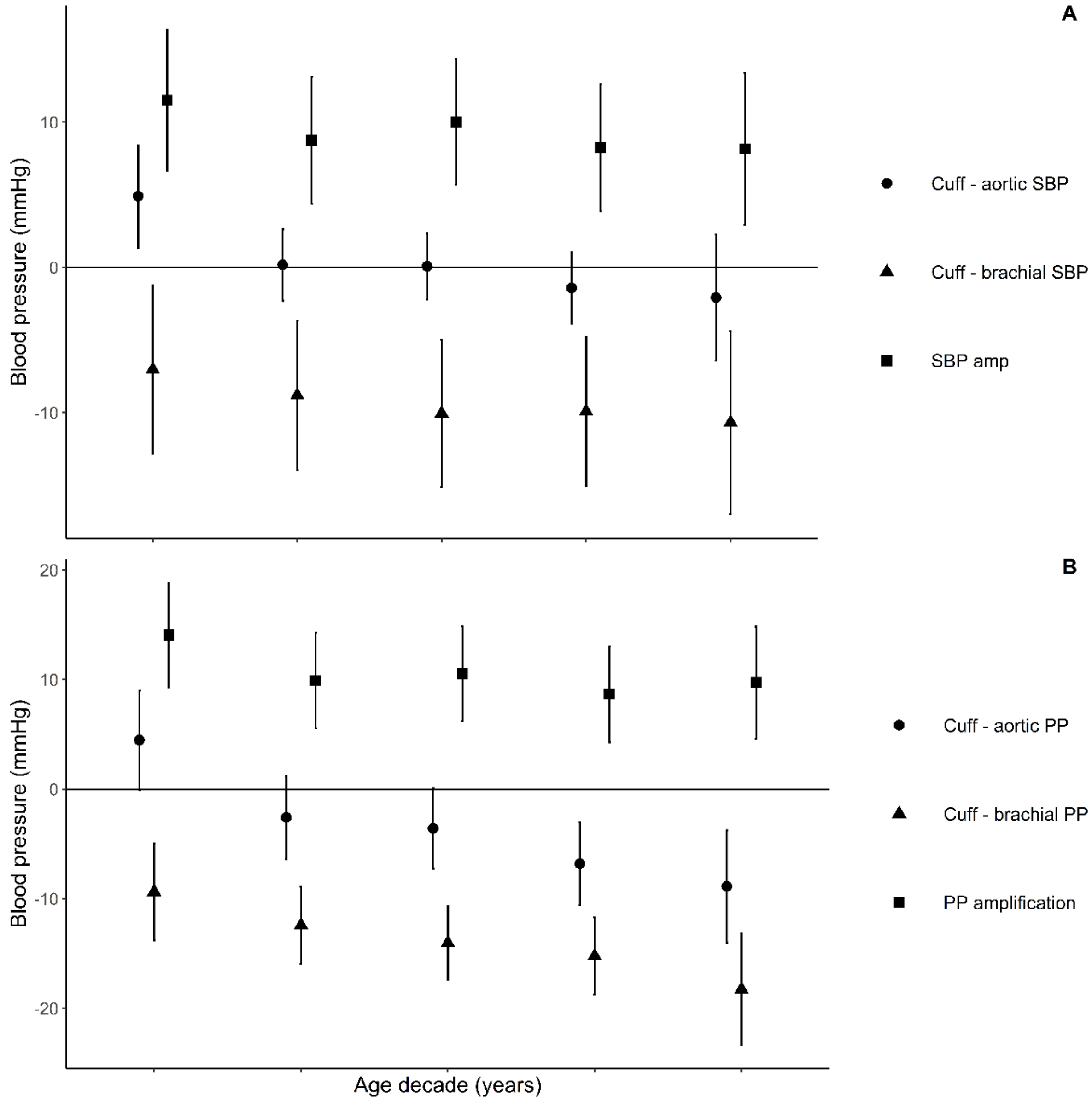
Online supplement Figure S6. Cuff blood pressure (BP) compared with invasive brachial systolic BP (SBP; A), diastolic BP (DBP; B) and pulse pressure (PP; C) measurements across decades of age and stratified according to the category of cuff BP control (according to the 2017 American Heart Association/American College of Cardiology arterial hypertension guidelines). Data are mean difference and 95% confidence interval (error bars). Data above the solid horizontal zero line indicates cuff BP is higher than invasive brachial BP and vice versa below the zero line. The number of subjects in each age and BP guideline grouping is shown in the table on the middle right of the figure. Within each BP category, there were only significant trends for the influence of age on cuff BP compared with invasive brachial BP for SBP in stage 2 hypertension, DBP in the elevated category and PP in stage 1 and 2 hypertension. Circles, normal BP; triangles, elevated BP; squares, stage 1 hypertension; crosses; stage 2 hypertension.



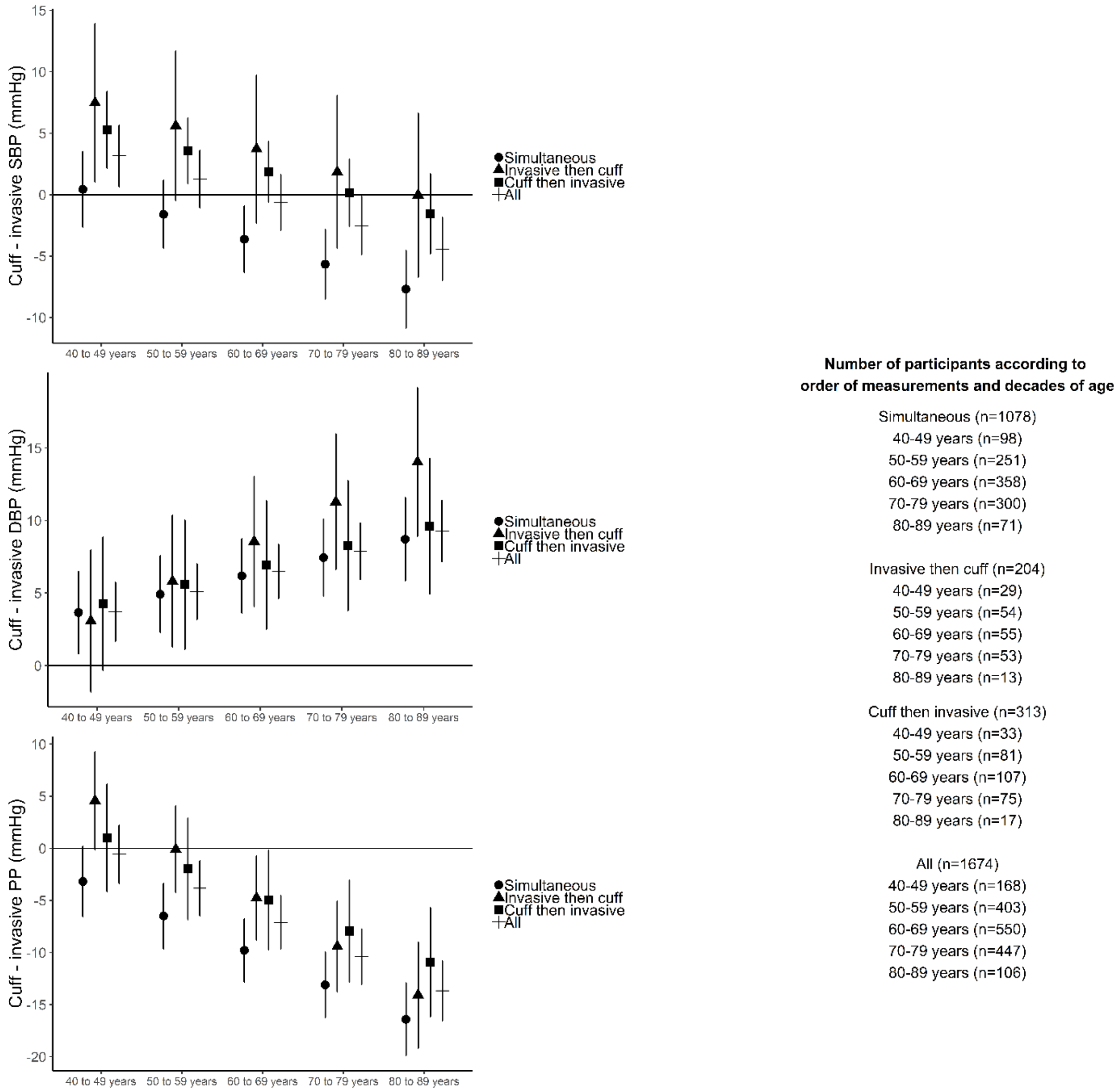
Online supplement Figure S7. Cuff blood pressure (BP) compared with invasive brachial systolic (SBP; A), diastolic (DBP; B) and pulse pressure (PP; C) measurements (y-axis) stratified by the type of catheter (fluid-filled or micromanometer tip) across ten-year age groups (x-axis). Data are mean difference and 95% confidence interval (error bars). The number of subjects in each age and catheter type grouping is shown in the table on the middle right of the figure. Data above the solid horizontal zero line indicates cuff BP is higher than invasive aortic BP and vice versa below the zero line.



Online supplement Figure S8. Cuff blood pressure (BP) compared with invasive brachial systolic (SBP; A), diastolic (DBP; B) and pulse pressure (PP; C) measurements (y-axis) stratified by the type of sphygmomanometer used (oscillometric or mercury) across decades of age (x-axis). Data are mean difference and 95% confidence interval (error bars). The number of subjects in each age and sphygmomanometer grouping is shown in the table on the middle right of the figure. Data above the solid horizontal zero line indicates cuff BP is higher than invasive brachial BP and vice versa below the zero line.



Online supplement Figure S9. The difference between cuff systolic blood pressure (SBP) and invasive aortic (circles) or invasive brachial (triangles) SBP is plotted alongside SBP amplification (SBP amp; invasive brachial SBP– invasive aortic SBP; squares) in panel A. The difference between cuff pulse pressure (PP) and invasive aortic (circles) or invasive brachial (triangles) PP isplotted with PP amplification (invasive brachial PP – invasive aortic PP; squares) in panel B. Data are mean and 95% confidence interval (error bars). Data above the solid horizontal zero line indicates cuff BP is higher than invasive BP and vice versa below the zero line. Data is from a subset of 372 subjects.



Online supplement Figure S10. Cuff blood pressure (BP) compared with invasive aortic systolic BP (SBP; A), diastolic BP (DBP; B) and pulse pressure (PP; C) measurements across decades of age and stratified according to the order of BP measurements. Data are mean difference and 95% confidence interval (error bars). Circles, cuff and invasive BP measured simultaneously; triangles, invasive BP measured just prior to cuff BP; squares, cuff BP measured just prior to invasive BP; crosses; all data together.

Online supplement references

1. Aakhus S, Torp H, Haugland T, Hatle L. Noninvasive estimates of aortic root pressures - external subclavian arterial pulse tracing calibrated by oscillometrically determined brachial arterial pressures. *Clin. Physiol.* 1993;13:573-586
2. Bhatt SD, Hinderliter AL, Stouffer GA. Influence of sex on the accuracy of oscillometric-derived blood pressures. *J. Clin. Hypertens.* 2011;13:112-119
3. Borow KM, Newburger JW. Noninvasive estimation of central aortic pressure using the oscillometric method for analyzing systemic artery pulsatile blood flow: Comparative study of indirect systolic, diastolic, and mean brachial artery pressure with simultaneous direct ascending aortic pressure measurements. *Am. Heart J.* 1982;103:879-886
4. Bos WJW, Van Goudoever J, Wesseling KH, Rongen GAPJM, Hoedemaker G, Lenders JWM, Van Montfrans GA. Pseudohypertension and the measurement of blood pressure. *Hypertension*. 1992;20:26-31
5. Cheng HM, Wang KL, Chen YH, Lin SJ, Chen LC, Sung SH, Ding PY, Yu WC, Chen JW, Chen CH. Estimation of central systolic blood pressure using an oscillometric blood pressure monitor. *Hypertens. Res.* 2010;33:592-599
6. Costello BT, Schultz MG, Black JA, Sharman JE. Evaluation of a brachial cuff and suprasystolic waveform algorithm method to noninvasively derive central blood pressure. *Am. J. Hypertens.* 2015;28:480-486
7. Cremer A, Butlin M, Codjo L, Coulon P, Ranouil X, Joret C, Coste P, Asmar R, Avolio A, Gosse P. Determination of central blood pressure by a noninvasive method (brachial bp and qkd interval). *J. Hypertens.* 2012;30:1533-1539
8. Ding FH, Li Y, Zhang RY, Zhang Q, Wang JG. Comparison of the sphygmocor and omron devices in the estimation of pressure amplification against the invasive catheter measurement. *J. Hypertens.* 2013;31:86-93
9. Jeon WK, Kim MA, Kim HL, Ki YJ, Rhee TM, Lim WH, Seo JB, Kim SH, Zo JH. Association between aortic knob width and invasively measured aortic pulse pressure. *Blood Press. Monit.* 2018
10. Laugesen E, Rossen NB, Peters CD, Maeng M, Ebbehoj E, Knudsen ST, Hansen KW, Botker HE, Poulsen PL. Assessment of central blood pressure in patients with type 2 diabetes: A comparison between sphygmocor and invasively measured values. *Am. J. Hypertens.* 2014;27:169-176
11. Lin MM, Cheng HM, Sung SH, Liao CF, Chen YH, Huang PH, Chen CH. Estimation of central aortic systolic pressure from the second systolic peak of the peripheral upper limb pulse depends on central aortic pressure waveform morphology. *J. Hypertens.* 2012;30:581-586
12. Nagle FJ, Naughton J, Balke B. Comparisons of direct and indirect blood pressure with pressure-flow dynamics during exercise. *J. Appl. Physiol.* 1966;21:317-320
13. Nakagomi A, Okada S, Shoji T, Kobayashi Y. Aortic pulsatility assessed by an oscillometric method is associated with coronary atherosclerosis in elderly people. *Blood Press.* 2016:1-8
14. Ohte N, Saeki T, Miyabe H, Sakata S, Mukai S, Hayano J, Niki K, Sugawara M, Kimura G. Relationship between blood pressure obtained from the upper arm with a cuff-type sphygmomanometer and central blood pressure measured with a catheter-tipped micromanometer. *Heart Vessels*. 2007;22:410-415
15. Ott C, Haetinger S, Schneider MP, Pauschinger M, Schmieder RE. Comparison of two noninvasive devices for measurement of central systolic blood pressure with invasive measurement during cardiac catheterization. *J. Clin. Hypertens. (Greenwich)*. 2012;14:575-579

16. Park CM, Korolkova O, Davies JE, Parker KH, Siggers JH, March K, Tillin T, Chaturvedi N, Hughes AD. Arterial pressure: Agreement between a brachial cuff-based device and radial tonometry. *J. Hypertens.* 2014;32:865-872
17. Pereira T, Maldonado J, Coutinho R, Cardoso E, Laranjeiro M, Andrade I, Conde J. Invasive validation of the complior analyse in the assessment of central artery pressure curves: A methodological study. *Blood Press. Monit.* 2014;19:280-287
18. Pucci G, Cheriyan J, Hubsch A, Hickson SS, Gajendragadkar PR, Watson T, O'Sullivan M, Woodcock-Smith J, Schillaci G, Wilkinson IB, McEniery CM. Evaluation of the vicorder, a novel cuff-based device for the noninvasive estimation of central blood pressure. *J. Hypertens.* 2013;31:77-85
19. Rossen NB, Laugesen E, Peters CD, Ebbehoj E, Knudsen ST, Poulsen PL, Botker HE, Hansen KW. Invasive validation of arteriograph estimates of central blood pressure in patients with type 2 diabetes. *Am. J. Hypertens.* 2014;27:674-679
20. Sueta D, Yamamoto E, Tanaka T, Hirata Y, Sakamoto K, Tsujita K, Kojima S, Nishiyama K, Kaikita K, Hokimoto S, Jinnouchi H, Ogawa H. The accuracy of central blood pressure waveform by novel mathematical transformation of non-invasive measurement. *Int. J. Cardiol.* 2015;189:244-246
21. Smulyan H, Siddiqui DS, Carlson RJ, London GM, Safar ME. Clinical utility of aortic pulses and pressures calculated from applanated radial-artery pulses. *Hypertension*. 2003;42:150-155
22. Smulyan H, Sheehe PR, Safar ME. A preliminary evaluation of the mean arterial pressure as measured by cuff oscillometry. *Am. J. Hypertens.* 2008;21:166-171
23. Smulyan H, Mukherjee R, Sheehe PR, Safar ME. Cuff and aortic pressure differences during dobutamine infusion: A study of the effects of systolic blood pressure amplification. *Am. Heart J.* 2010;159:399-405
24. Takazawa K, Kobayashi H, Shindo N, Tanaka N, Yamashina A. Relationship between radial and central arterial pulse wave and evaluation of central aortic pressure using the radial arterial pulse wave. *Hypertens. Res.* 2007;30:219-228
25. Takazawa K, Kobayashi H, Kojima I, Aizawa A, Kinoh M, Sugo Y, Shimizu M, Miyawaki Y, Tanaka N, Yamashina A, Avolio A. Estimation of central aortic systolic pressure using late systolic inflection of radial artery pulse and its application to vasodilator therapy. *J. Hypertens.* 2012;30:908-916
26. Weber T, Wassertheurer S, Rammer M, Maurer E, Hametner B, Mayer CC, Kropf J, Eber B. Validation of a brachial cuff-based method for estimating central systolic blood pressure. *Hypertension*. 2011;58:825-832
27. Berliner K, Yildiz M, Garnier B, Lee DH, Fujiy H. Blood pressure measurements in obese persons - comparison of intra-arterial and auscultatory measurements. *Am. J. Cardiol.* 1961;8:10-&
28. Melamed R, Johnson K, Pothen B, Sprenkle MD, Johnson PJ. Invasive blood pressure monitoring systems in the icu: Influence of the blood-conserving device on the dynamic response characteristics and agreement with noninvasive measurements. *Blood Press. Monit.* 2012;17:179-183
29. Muecke S, Bersten A, Plummer J. The mean machine; accurate non-invasive blood pressure measurement in the critically ill patient. *J. Clin. Monit. Comput.* 2009;23:283-297
30. Omboni S, Parati G, Groppelli A, Ulian L, Mancia G. Performance of the am-5600 blood pressure monitor: Comparison with ambulatory intra-arterial pressure. *J Appl Physiol (1985)*. 1997;82:698-703
31. Picone DS, Schultz MG, Peng X, Black JA, Dwyer N, Roberts-Thomson P, Chen CH, Cheng HM, Pucci G, Wang JG, Sharman JE. Discovery of new blood pressure

phenotypes and relation to accuracy of cuff devices used in daily clinical practice. *Hypertension*. 2018;71:1239-1247

32. Raftery EB, Ward AP. The indirect method of recording blood pressure. *Cardiovasc. Res.* 1968;2:210-218