High blood pressure in children and adults: The same, but different

Joshua Samuels

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UTHealth® The University of Texas Health Science Center at Houston | McGovern Medical School

HPAHP Houston Pediatric and Adolescent Hypertension Program

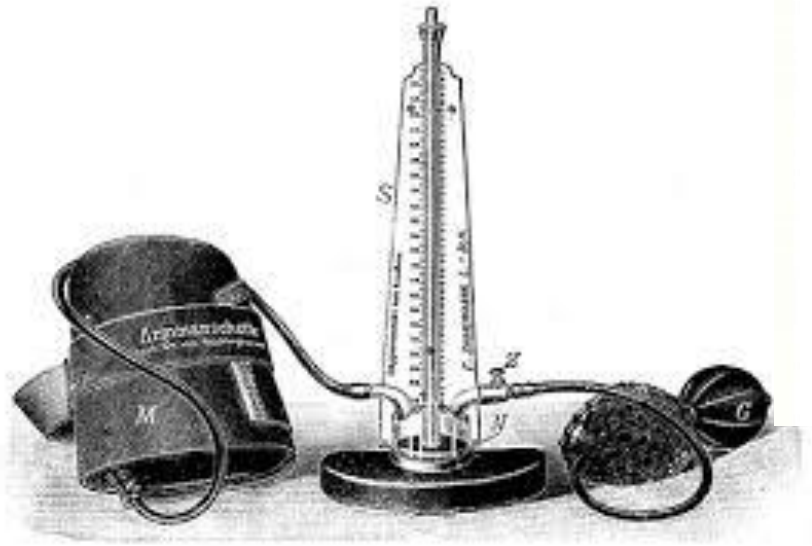
Children's Memorial Hermann® Hospital

I have no financial conflicts of interest related to this talk. The content is my own and not representative of any outside organization or guideline recommendations.

Hypertension: Background and Importance

History of blood pressure measurement

1733 Reverend Stephen Hales records the first blood pressure measurement on a horse



1905 Dr. Nikolai Korotkoff introduced the auscultatory method and discovered the difference between systolic blood pressure and diastolic blood pressure

1976 Dinamap 825 introduced. The first commercially available oscillometric blood pressure device.

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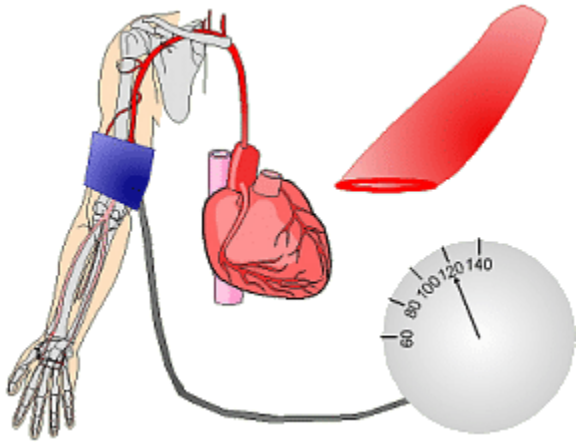
Types of blood pressure measurements

Method of Measurement

- Auscultatory
- Oscillometric
- Intra-arterial (Invasive)

Location of Measurement

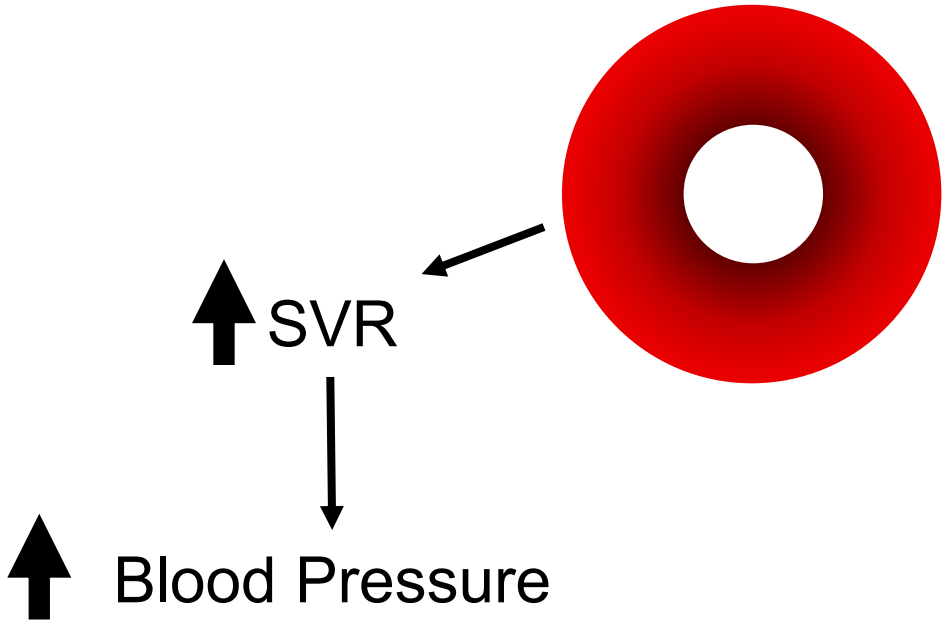
- Office BP
- Home BP
- ABPM



Regulation of Blood Pressure

- BP = SVR x CO

Sympathetic stimulation:
Epinephrine
Norepinephrine

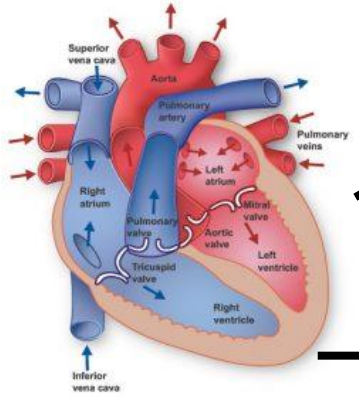


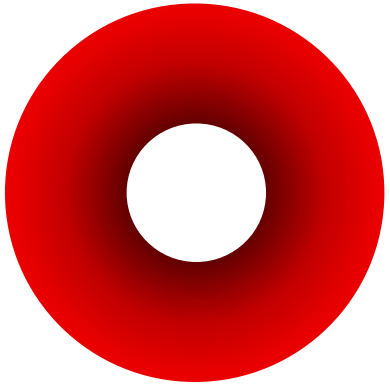
Regulation of Blood Pressure

- BP = SVR x CO

Vessel Diameter:
Autonomic NS
Volume (renal factors)
Viscosity (Hemoglobin)
Hormones

CO= HR x SV





HR

SV

CO

SVR

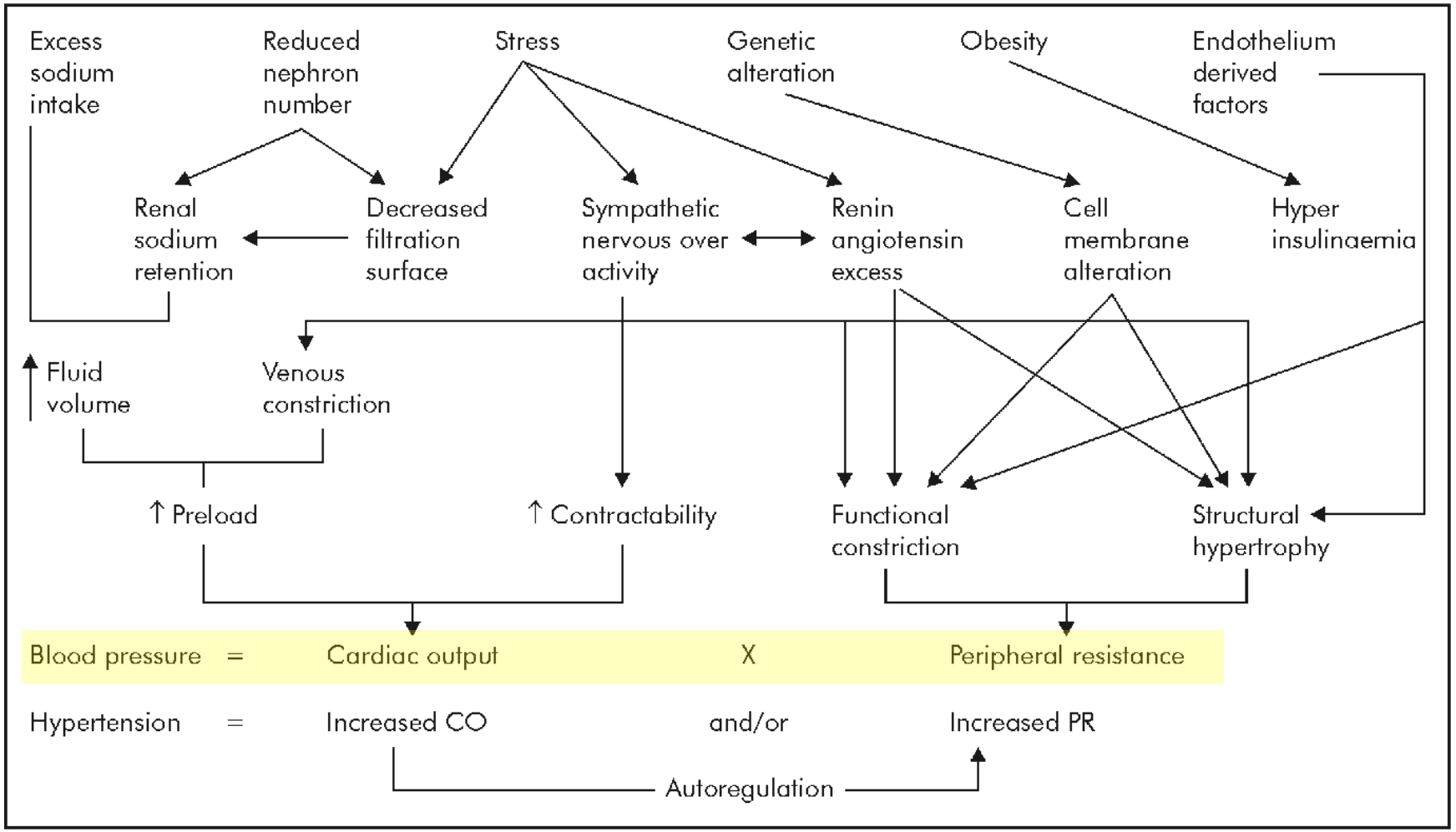
Preload

Afterload

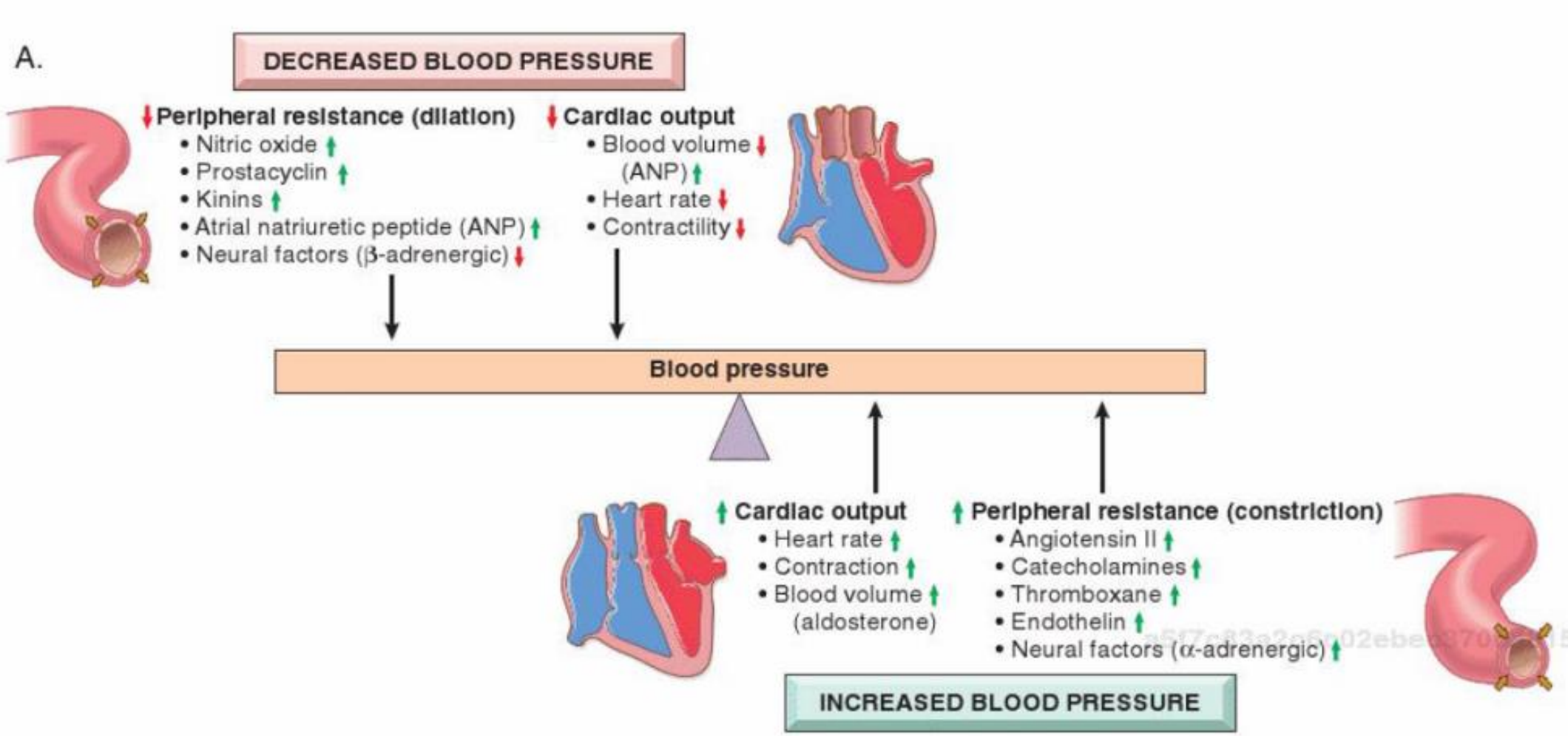
Contractility

Blood Pressure

Lots more to the story



Neurohormonal Control of Blood Pressure



Chronic Hypertension

- Sustained hypertension requires participation by the kidney, which normally responds to hypertension by eliminating sodium and water

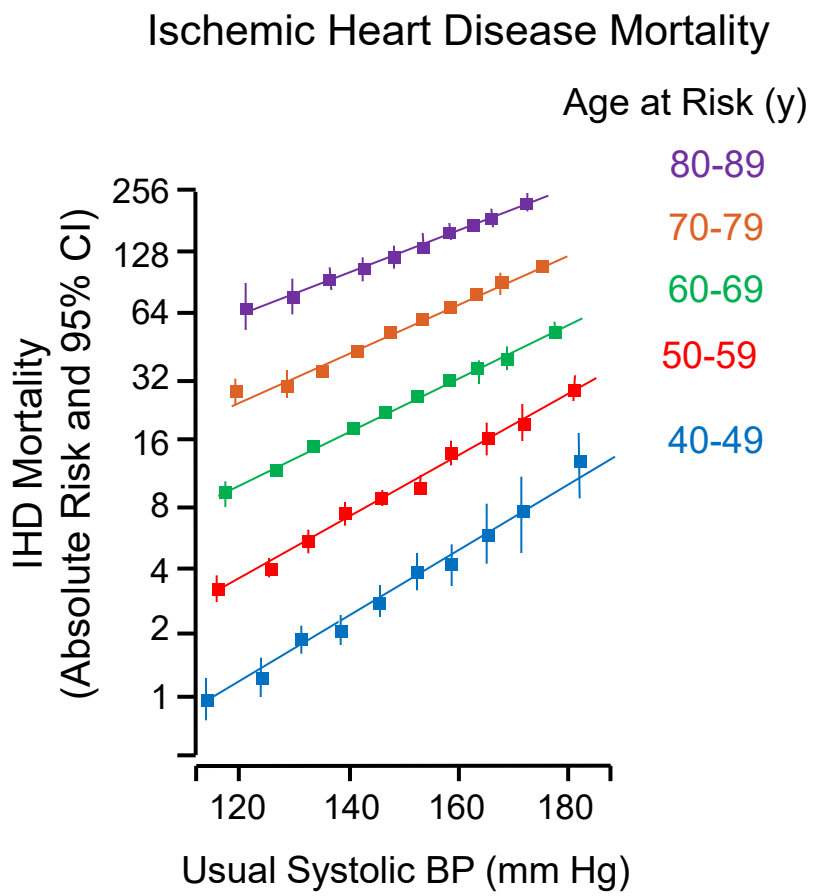
- In established hypertension, both increased blood volume and increased peripheral vascular resistance contribute to the increase in blood pressure

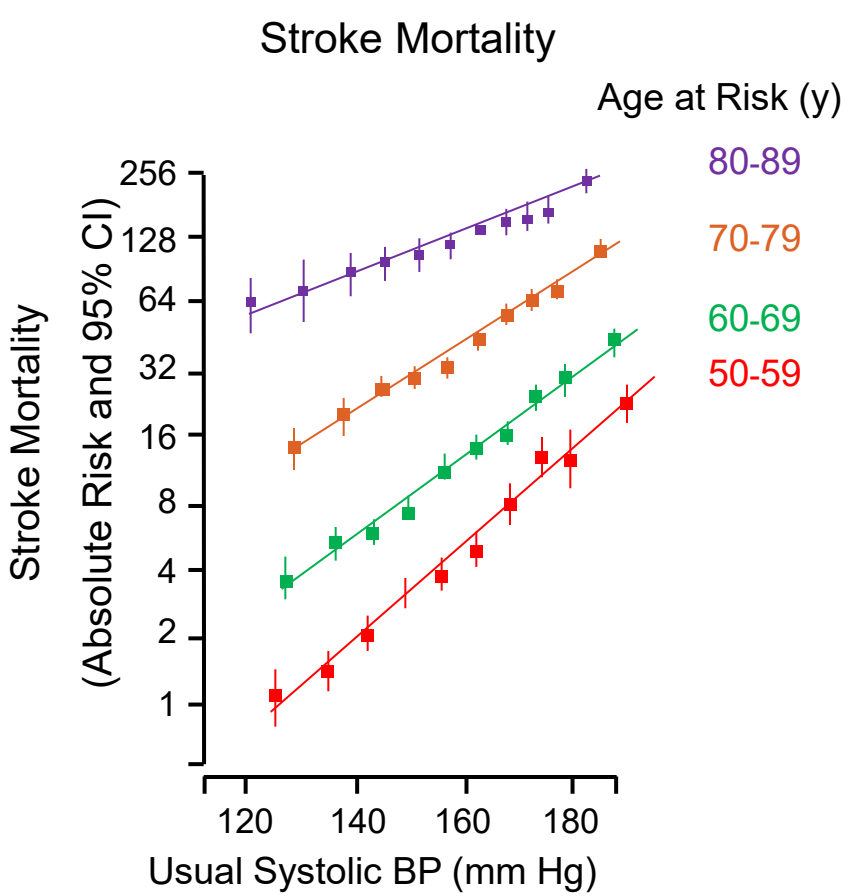
Sobering facts about hypertension (HTN)

- Hypertension is the number one reason adults see a physician
- More than one in three adults has hypertension
- The treatment of hypertension is the most effective intervention in reducing CV risk
- Inadequately treated hypertension is the #1 attributable risk for death worldwide

Hypertension and Mortality: IHD and CVA mortality

One Million Adults, 61 Prospective Studies





Prospective Studies Collaboration *Lancet.* 2002; PMID: 12493255

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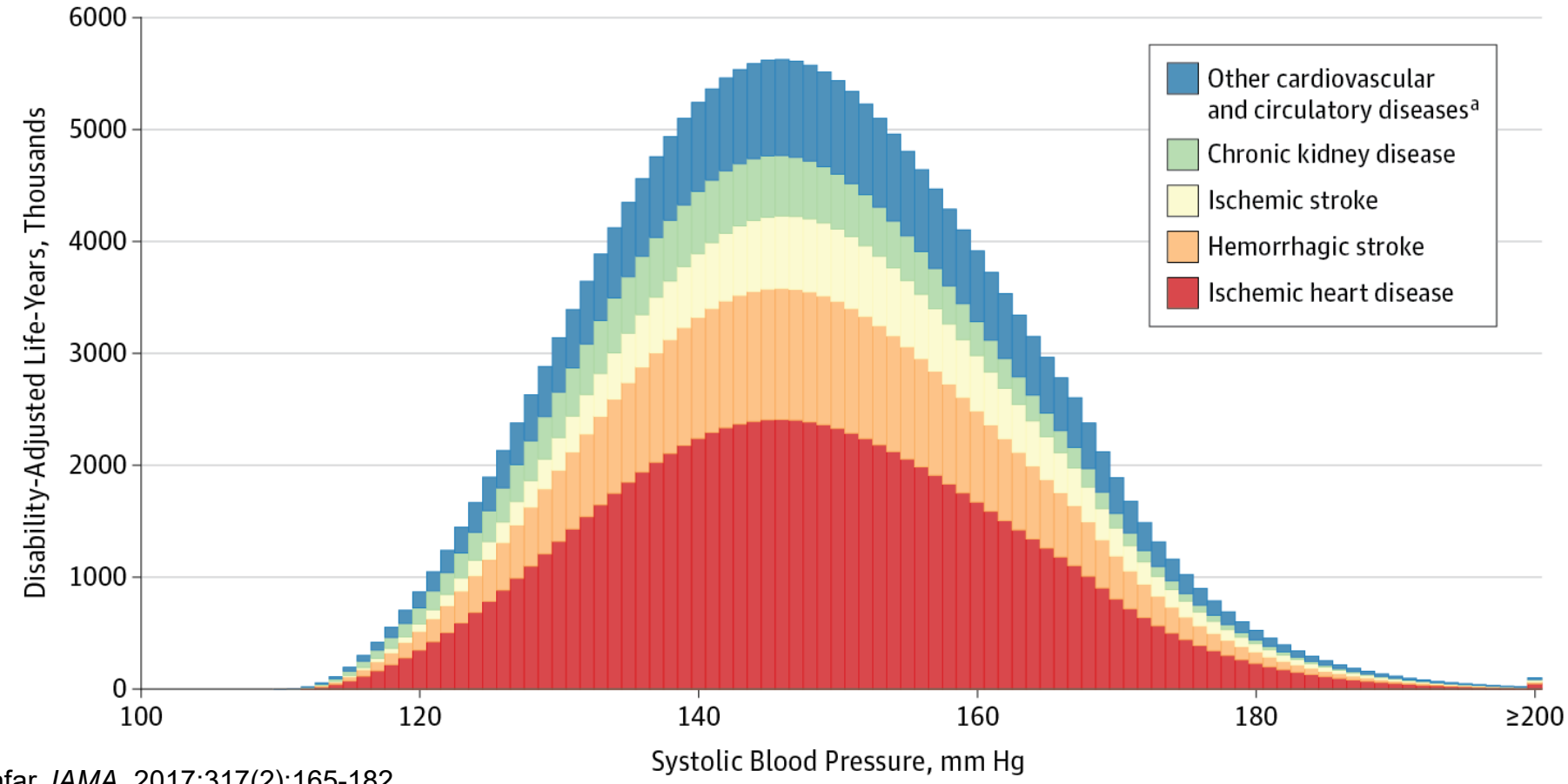
Hypertension and DALY: CVD, CVA, CKD



Forouzananfar *JAMA*. 2017;317(2):165-182

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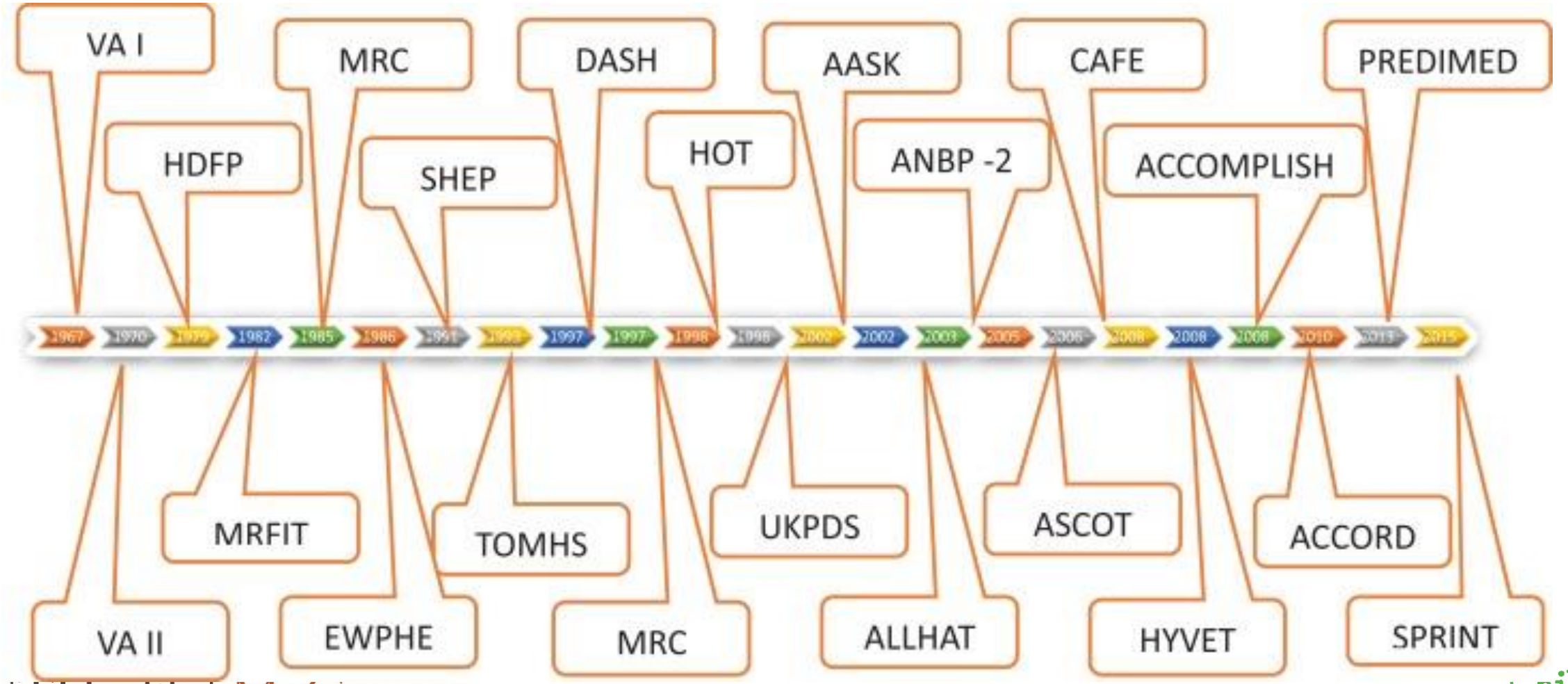
Timeline of HTN Studies



Frontiers in cardiovascular medicine, *3*, 3.

Timeline of HTN Studies

TABLE 1 | Time line of hypertension.

Study	Year	Primary question/issues	Conclusion of the study/impact
VA-1st	1967	Is severe hypertension (dias) 115–129 treatable	Yes, less stroke/CHF
VA-2nd	1970	Same question for moderate BP (90–115)	Treated group less stroke/CHF
HDFP	1979	Goal-oriented BP therapy better than usual therapy?	Yes. Targeting BP goal of dias 90 reduced CVA by 36% more
MRFIT	1982	Lowering BP and lipid and stopping smoking may reduce CHD mortality	No difference in CHD mortality 17.9 vs. 19.3% (per 1000)
MRC	1985	Hypertension treatment in younger patients (35–64) is beneficial also?	Yes. Total CV events 286 in treated group vs. 352 in control ($p < 0.05$)
EWHPE	1986	Hypertension treatment in exclusively older people (60) beneficial?	Yes. Mortality reduction 26% decrease in CV mortality 43%
SHEP	1991	Is treatment of systolic hypertension beneficial	Treating isolated systolic hypertension over 160 prevented stroke (ARR 3%), MI, and all CVD
TOMHS	1993	Outcome of 5 different classes BP meds vs. placebo	BP lowering similar among all classes CV events and death reduced (ARR 2.2%)
DASH	1997	Does Mediterranean diet with or without salt restriction lowers BP?	Compared to western diet it lowers bp and salt restriction adds to the effect
MRC	1997	Salt reduction in older people Lowers BP?	Reducing salt intake to 2 g Na lowered BP 7.2/3.2 mmHg

Timeline of HTN Studies

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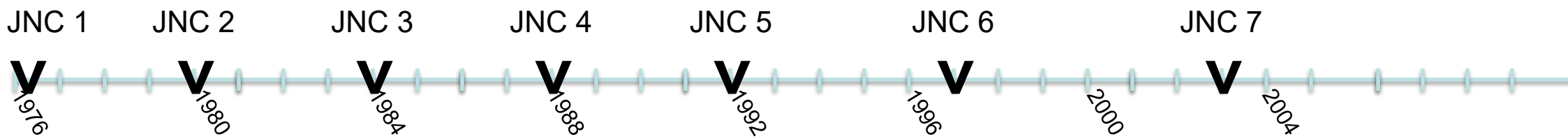
Study	Year	Primary question/issues	Conclusion of the study/impact
UKPDS	1998	Multiple studies 2 involved BP Tight BP control and agents (captopril vs. atenolol)	Group target <150/85 had 32, 44, and 34% less death, stroke, and retinopathy, respectively. No difference in ACEI group vs. BB
AASK	2002	To reduce progression of CKD BP goal mean 92 better than 105 ACEI, BB, or CCB better as drug?	No difference in mean BP goal of 92 vs. 105. ACEI use protected progression of CKD better than CCB
ALLHAT	2002	Compared to old thiazide (CTDN) new class of BP drugs CCB, ACEI, or AB has better outcome? AB gr closed for high incidence of CHF	No difference in MI, mortality, or CKD progression among 3 classes. CTDN vs. CCB for CHF RR 1.38. CTDN vs. ACEI for stroke and CHF RR 1.15 and 1.19
ANBP2	2003	ACEI vs. thiazide (HCTZ) for CV outcomes in Australian	In this study unlike ALLHAT, ACE was better all CV events RR was 0.88
ASCOT	2005	CCB and ACE inhibitor compared to BB and thiazide for BP control	CCB and ace inhibitor combination group showed better CV outcomes
CAFÉ	2006	Why Betablocker for BP does not prevent stroke	Betablocker lowers peripheral BP but not central (aortic) BP
HYVET	2008	Should we treat elderly (>80) hypertensive (sys > 160)	Yes. Treated group had 30% less stroke and 64% less CHF, 21% less death
AC-SH	2008	Combination of ACEI + CCB better than ACEI + thiazide (HCTZ)	ACEI + CCB group had 2.2% ARR of composite CV events and death
ACCRD	2010	In diabetics Goal BP sys < 120 better than 140?	No significant difference in mortality, total CV events, or renal protection
SPRINT	2015	Same as ACCORD but in non-diabetic	27% improved all-cause mortality and 25% improvement in primary CV outcomes

Frontiers in cardiovascular medicine, *3*, 3.

Timeline of Hypertension Guidelines

Adult Guidelines



New Adult Clinical Practice Guidelines

CLINICAL PRACTICE GUIDELINES

2025 AHA/ACC/AANP/AAPA/ABC/ACCP/ACPM/AGS/AMA/ASPC/NMA/PCNA/SGIM Guideline for the Prevention, Detection, Evaluation and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines

Developed in Collaboration With and Endorsed by American Academy of Physician Associates; American Association of Nurse Practitioners; American College of Clinical Pharmacy; American College of Preventive Medicine; American Geriatrics Society; American Medical Association; American Society of Preventive Cardiology; Association of Black Cardiologists; National Medical Association; Preventive Cardiovascular Nurses Association; and the Society of General Internal Medicine.

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Jones, et.al. *Hypertension*. 2025 PMID: 40811516

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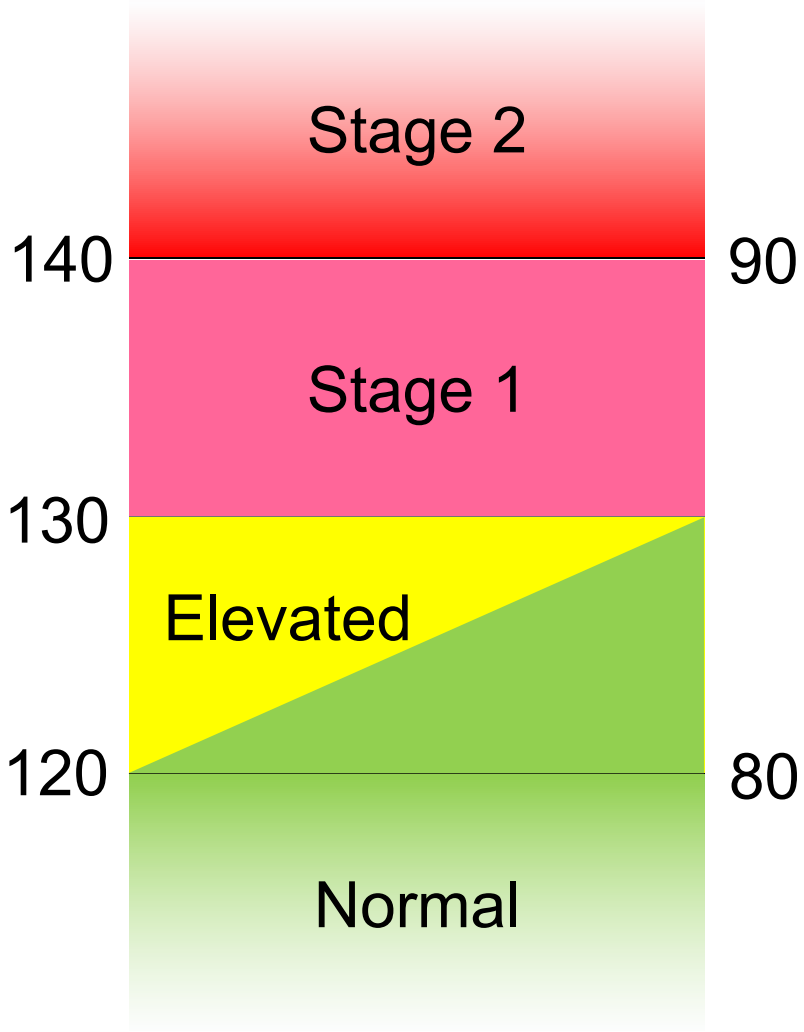
What is Hypertension?

- Thresholds



What is Hypertension?

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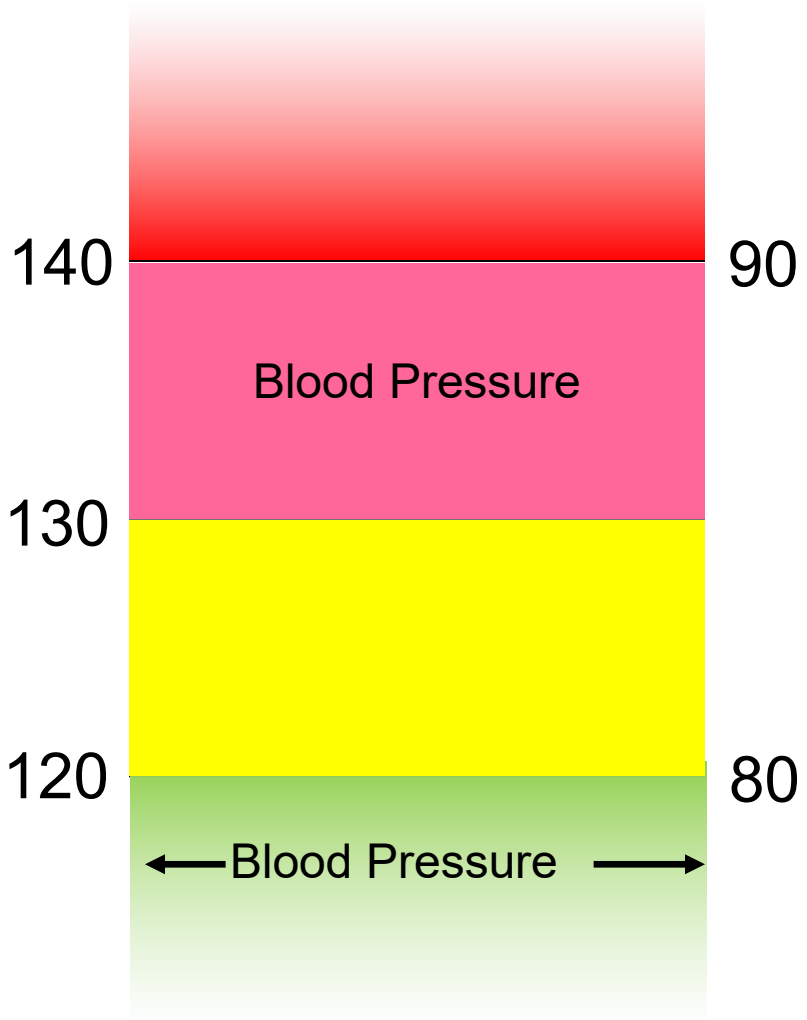

BP classification

Table 4. Categories of Blood Pressure in Adults*

	SBP		DBP
BP Category			
Normal	<120 mm Hg	and	<80 mm Hg
Elevated	120 to 129 mm Hg	and	<80 mm Hg
Hypertension			
Stage 1	130 to 139 mm Hg	or	80 to 89 mm Hg
Stage 2	≥140 mm Hg	or	≥90 mm Hg

Jones, et.al. *Hypertension*. 2025 PMID: 40811516

Children are NOT little adults!

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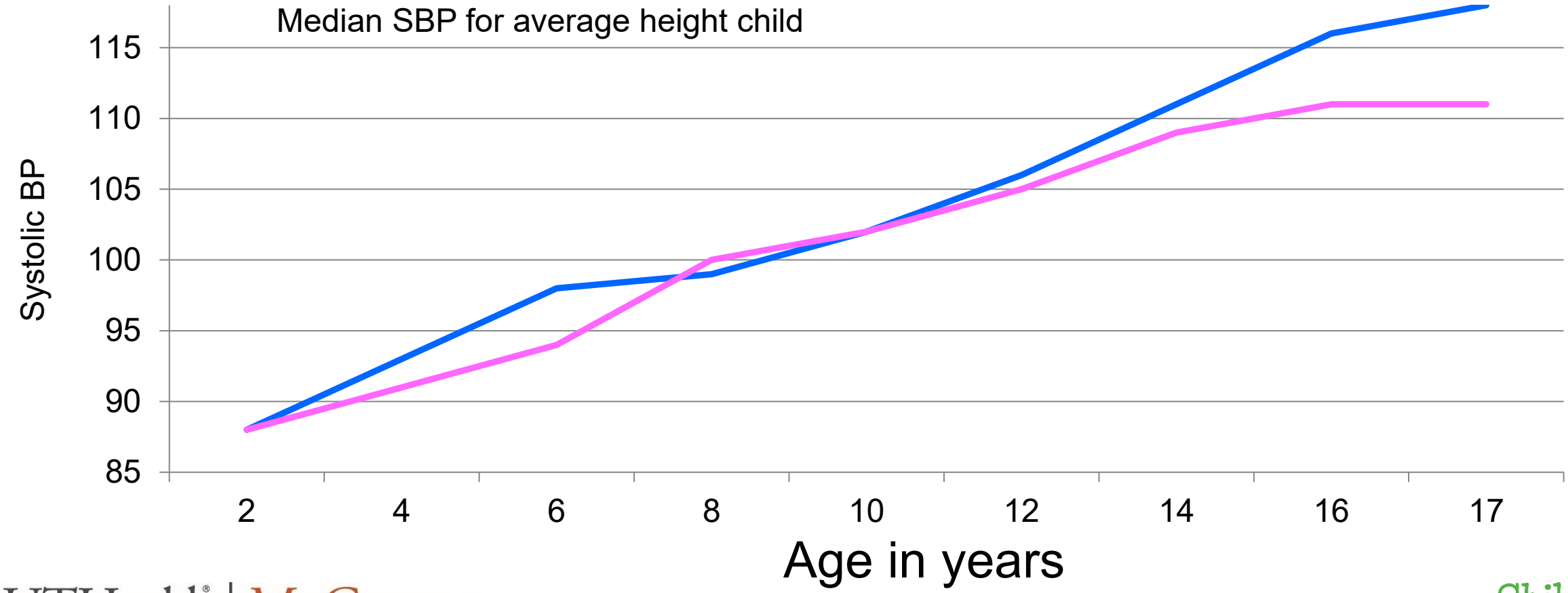
Blood pressure increases gradually during childhood



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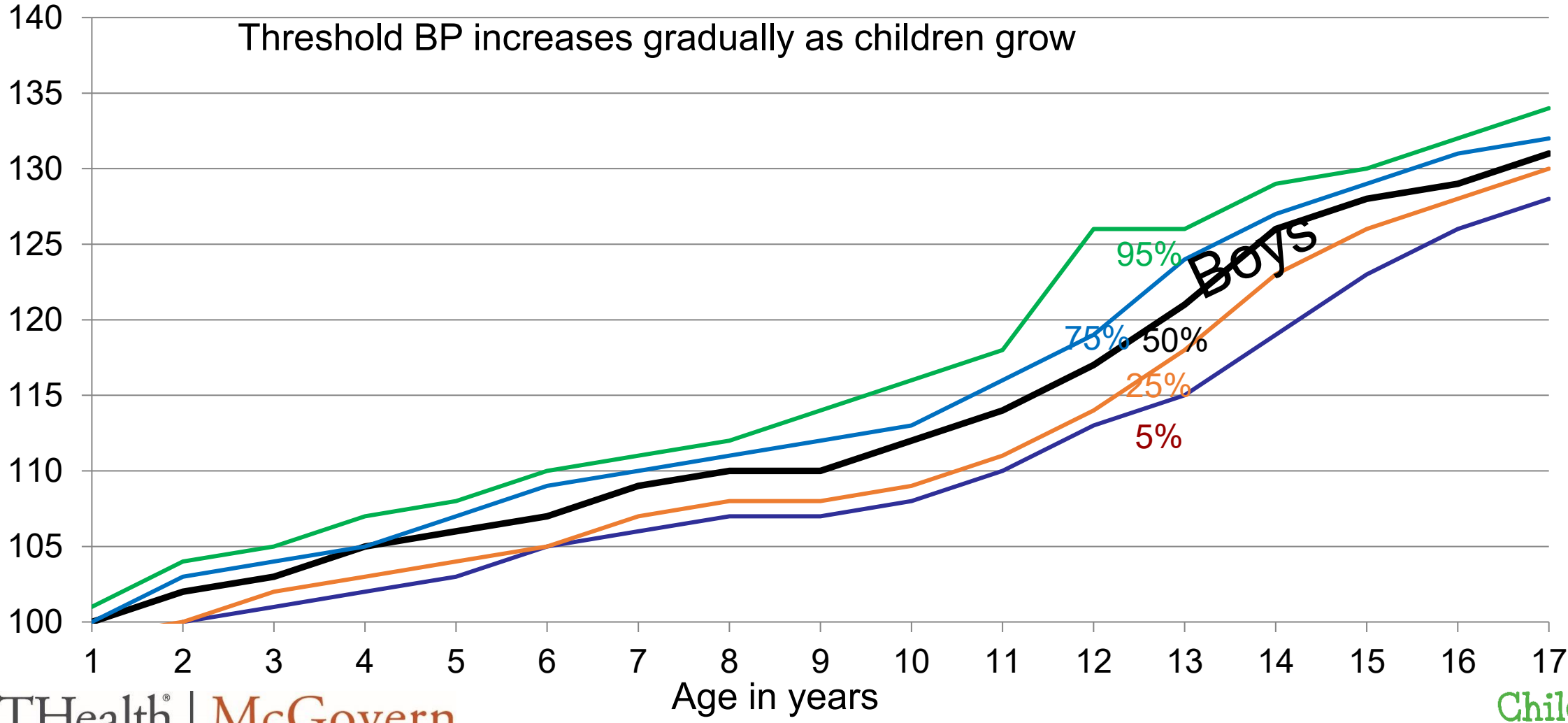
90th Percentile Systolic Values (Various heights)



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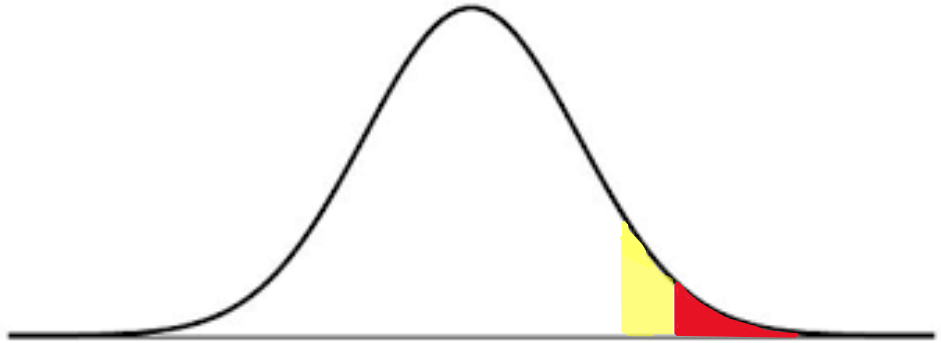
One size does NOT fit all

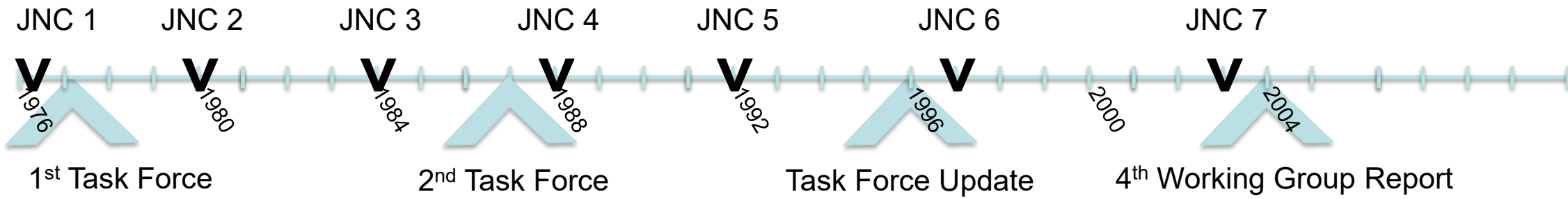
History of Pediatric Hypertension Guidelines

- Before 1977, no accepted normative data
  Adult definitions used (> 140/90 for all ages)
- 1977: 1st Task Force Report
  Normative data for children available
  HTN defined as ≥95th percentile for age and gender
- 1987: 2nd Task Force Report
  Additional data for over 70,000 children
- 1996: Task Force Update
  Incorporation of height percentiles to BP norms
- 2004: 4th Working Group Report
  Introduced "pre-hypertensive" category at ≥ 90th percentile
- 2017: AAP Clinical Practice Guidelines



Timeline of Hypertension Guidelines

Adult Guidelines



Pediatric Guidelines

Clinical Practice Guidelines

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CLINICAL PRACTICE GUIDELINE Guidance for the Clinician in Rendering Pediatric Care

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Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents

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Flynn et al, *Pediatrics* 2017; 140:e20171904 PMID: 28827377

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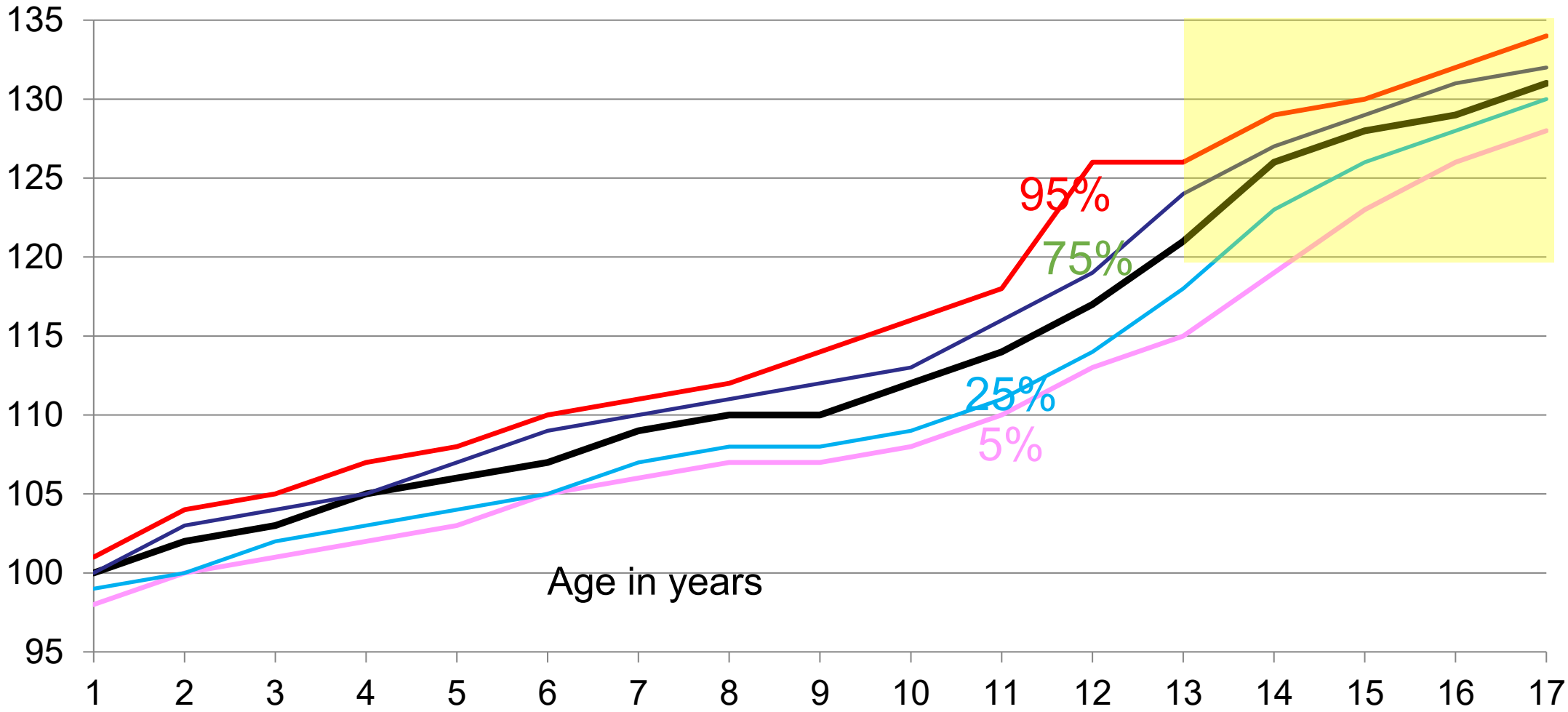
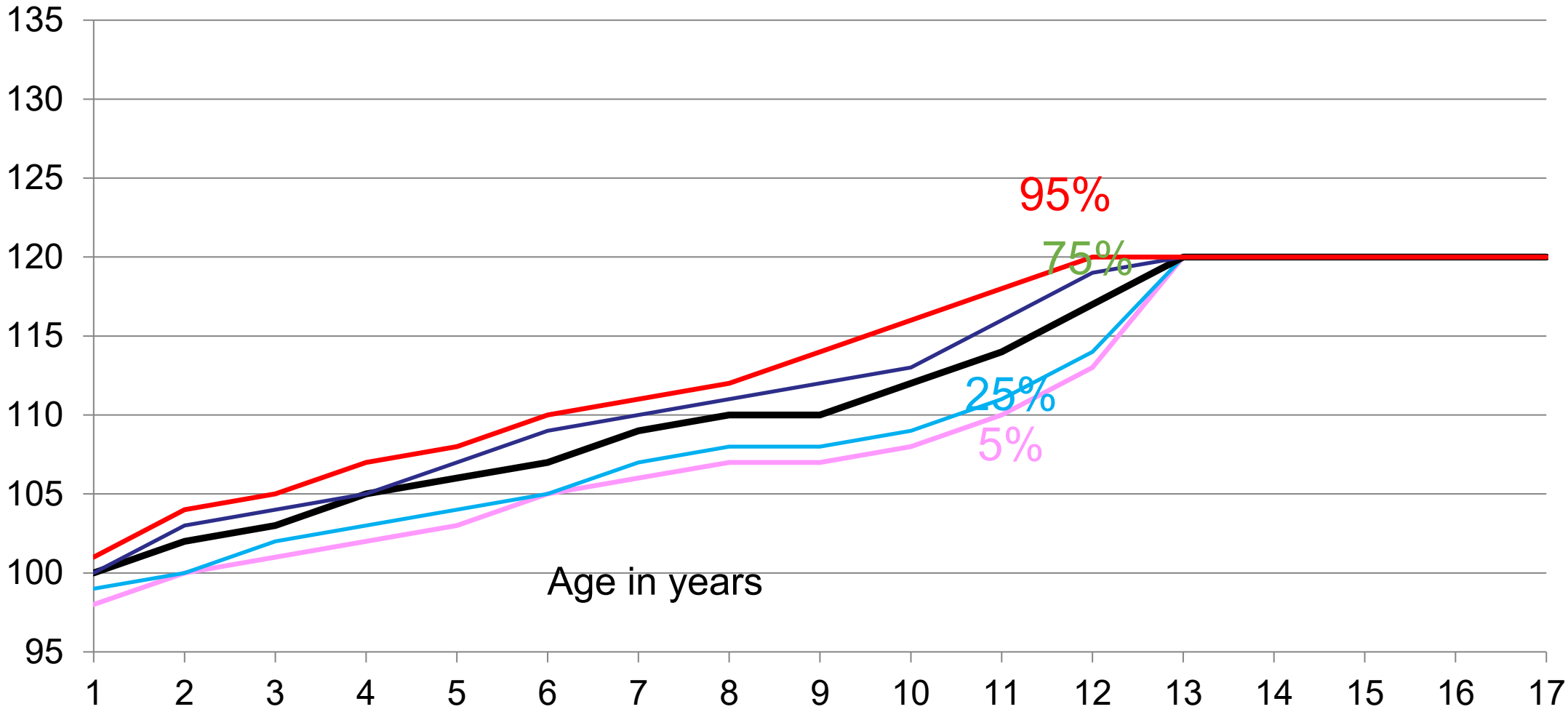
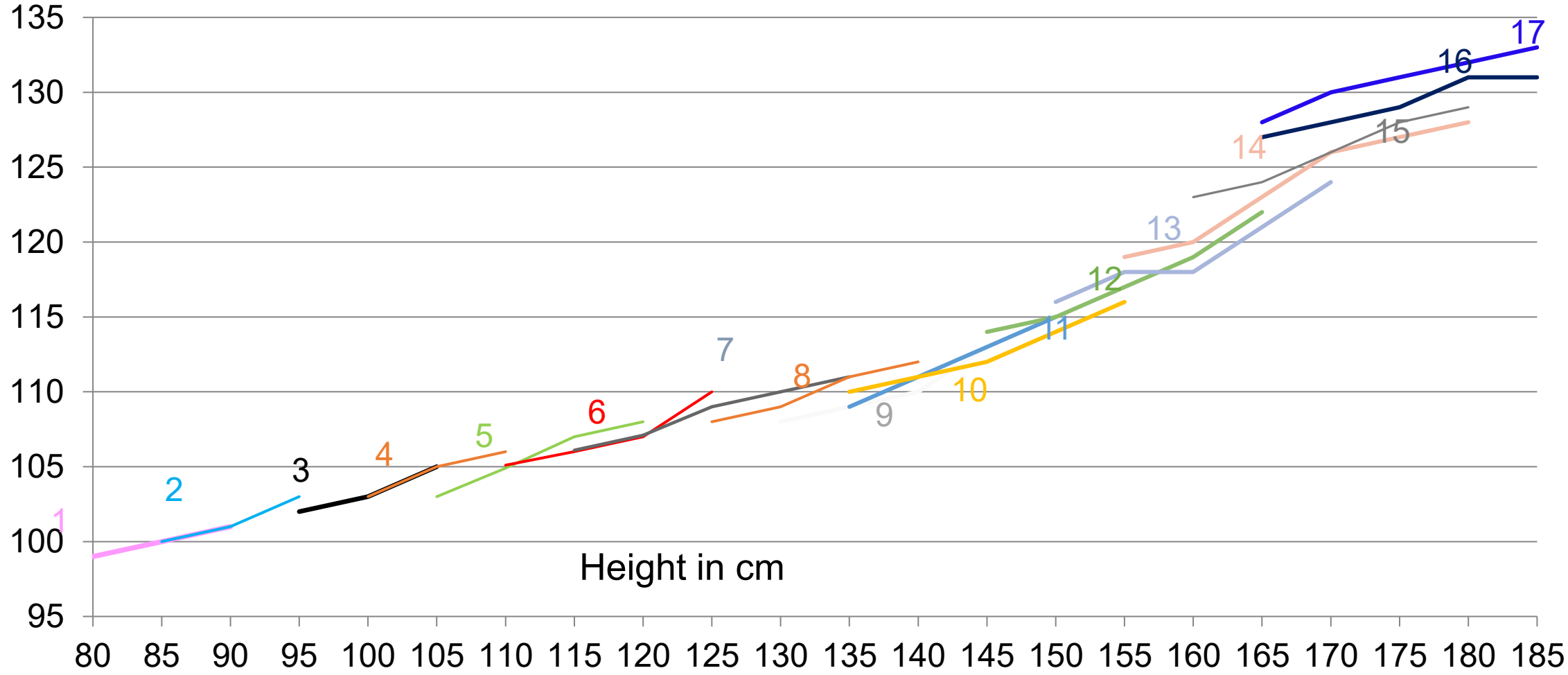
90th Percentile Systolic Values (various heights)



Elevated BP: Systolic Values (various heights)



90th Percentile Systolic Values (various heights)



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KAS 3: Diagnosis of Hypertension

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Trained health care professionals in the office setting should make a diagnosis of HTN if a child or adolescent has auscultatory confirmed BP readings ≥ 95th percentile* on 3 different visits

*(or ≥ 130/80 in children >13 years)

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Flynn (2017) *Pediatrics* PMID: 28827377

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Blood pressure values for Ages 1+

TABLE 4 BP Levels for Boys by Age and Height Percentile

Age (y)	BP Percentile	SBP (mm Hg)						DBP (mm Hg)						
		Height Percentile or Measured Height						Height Percentile or Measured Height						
11	Height (in)	53	54	55.7	57.6	59.6	61.3	62.4						
	Height (cm)	134.7	137.3	141.5	146.4	151.3	155.8	158.6						
1	Median BP	99	99	101	102	103	104	106						
	Elevated BP	110	111	112	114	116	117	118						
	Stage 1 HTN	114	114	116	118	120	123	124						
2	Stage 2 HTN	126	126	128	130	132	135	136						
	50th	87	87	88	89	89	90	91	43	43	44	44	45	46	46
	90th	100	100	101	102	103	103	104	55	55	56	56	57	58	58
	95th	104	105	105	106	107	107	108	57	58	58	59	60	61	61
	95th + 12 mm Hg	116	117	117	118	119	119	120	69	70	70	71	72	73	73
3	Height (in)	36.4	37	37.9	39	40.1	41.1	41.7	36.4	37	37.9	39	40.1	41.1	41.7
	Height (cm)	92.5	93.9	96.3	99	101.8	104.3	105.8	92.5	93.9	96.3	99	101.8	104.3	105.8
	50th	88	89	89	90	91	92	92	45	46	46	47	48	49	49
	90th	101	102	102	103	104	105	105	58	58	59	59	60	61	61
	95th	106	106	107	107	108	109	109	60	61	61	62	63	64	64
	95th + 12 mm Hg	118	118	119	119	120	121	121	72	73	73	74	75	76	76

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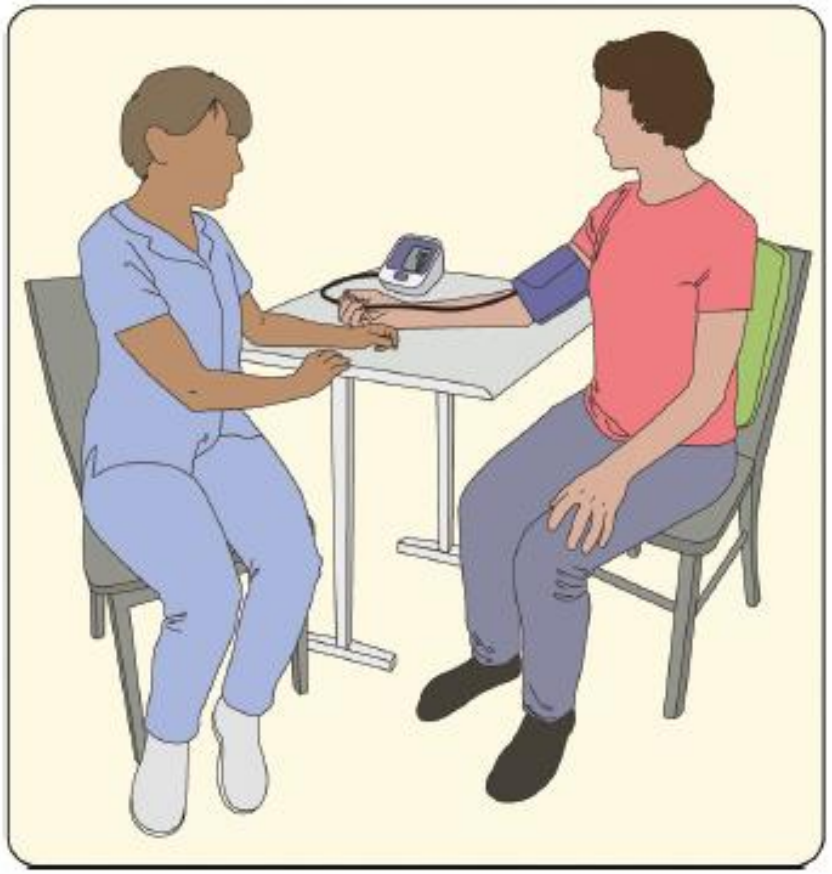
Blood Pressure Classification

- In young children, blood pressure thresholds are based on population norms (and thus percentiles)
- Teens >13 years old have static BP thresholds

HTN Classification	Children Aged 1-12 years(%ile)	Anyone ≥ 13 years old (mmHg)
Stage 2 Hypertension	≥95th + 12mmHg or ≥140/90 (lower)	≥140/90
Stage 1 Hypertension	≥95th to <95th + 12mmHg or 130/80 to 139/89 (lower)	130-139 80-89
Elevated Blood Pressure	≥90th or ≥120/80 mmHg (lower) to <95th	120-129 <80
Normotensive	<90th	<120/<80

Office BP Measurement

Office Blood Pressure Measurement



1. The patient should avoid caffeine, exercise, and smoking for at least 30 minutes before measurement. Ensure the patient has emptied their bladder.
2. Use a blood pressure device that has been validated for accuracy (validatebp.org).
3. Use the correct cuff size on a bare arm.
4. The patient's arm should be supported at heart level.
5. Have the patient relax, sitting in a chair (feet on floor, legs uncrossed, and back supported) for more than 5 minutes of rest.
6. Neither the patient nor the clinician should talk during the rest period or during the measurement. The patient should not be using their phone.
7. Blood pressure measurement should be taken in a temperature-controlled room.
8. Take 2 or more blood pressure measurements at least 1 minute apart. Average the readings, and provide the patient their blood pressure readings both verbally and in writing.

KAS 1: BP Measurement Frequency

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Key Action Statement 1. BP should be measured annually in children and adolescents ≥3 years of age (grade C, moderate recommendation).

Aggregate Evidence Quality	Grade C
Benefits	Early detection of asymptomatic HTN; prevention of short- and long-term HTN-related morbidity
Risks, harm, cost	Overtesting, misclassification, unnecessary treatment, discomfort from BP measurement procedure, time involved in measuring BP
Benefit–harm assessment	Benefit of annual BP measurement exceeds potential harm
Intentional vagueness	None
Role of patient preferences	Increased visit time, discomfort of cuff
Exclusions	None
Strength	Moderate recommendation
Key references	10,60,102,103

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BP Measurement & Classification

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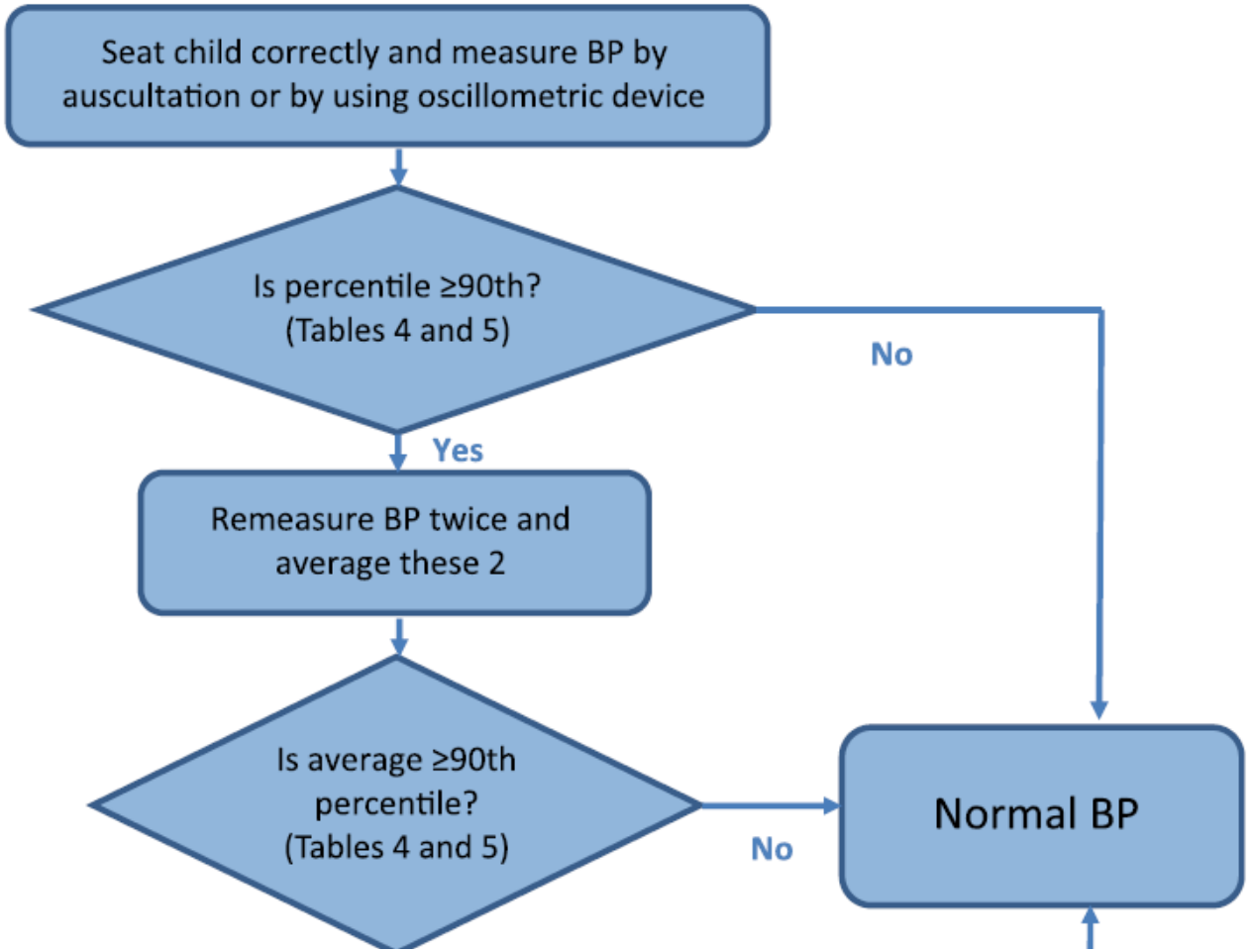

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Hypertension Evaluation in Youth

Evaluation of youth with hypertension is focused on 3 main areas:

1. Search for an identifiable cause of hypertension
2. Search for signs of hypertensive target organ damage
3. Search for *OTHER* cardiovascular risk factors

Physical Exam

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- BP in both arms
- Funduscopic
- Thyroid
- Cardiovascular - Auscultation, Carotids, Pulses
- Pulmonary
- Abdomen - Bruits, AAA, masses
- Extremities
- Neurological

Table 64. Physical Examination for Evaluation of Hypertension and CKD

Severity of hypertension; ECF volume status
Overweight or obesity as a cause of hypertension, CVD risk factor
Hypertensive retinal disease as a sign of end-organ damage, diabetic eye disease
Coexisting peripheral vascular disease, coarctation of aorta
Hyperthyroidism, hypothyroidism, Cushing's syndrome, acromegaly, pheochromocytoma, neurofibromatosis, scleroderma as a cause of hypertension
Heart failure as a sign of end-organ damage, arrhythmias, valvular or congenital heart disease
Renal artery disease, polycystic kidney disease, or congenital anomalies of the urinary tract as a cause of CKD and hypertension, coexisting aortic aneurysm
Stroke as a sign of end-organ damage; CNS causes of neurogenic hypertension

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Laboratory Tests

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- Routine
  - ECG (in adults only)
  - Urinalysis
  - Blood Glucose
  - Hematocrit, potassium, calcium, creatinine (or eGFR)
  - Lipid profile
  - Optional: Urine albumin excretion or albumin/creatinine ratio
- More extensive testing not generally indicated unless BP control not obtained or secondary HTN suspected

Table 49. Laboratory Measurements for Ascertainment of CKD

For all patients at increased risk for CKD:

- Serum creatinine to estimate GFR;
- Albumin-to-creatinine or protein-to-creatinine ratio in a first-morning or random untimed "spot" urine specimen;
- Examination of the urine sediment or dipstick for red blood cells and white blood cells.

For patients found to have CKD:

- Imaging of the kidneys, usually by ultrasound;
- Serum electrolytes (sodium, potassium, chloride and bicarbonate).

Table 50. Measurements for Ascertainment of CVD and CVD Risk Factors in CKD

- 12-lead EKG
- Serum glucose
- Fasting lipid panel
- Height and weight to calculate BMI

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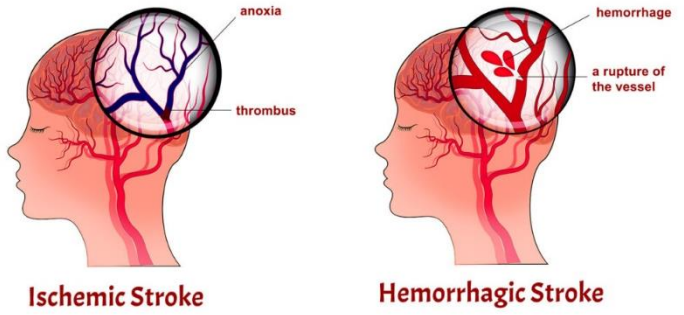
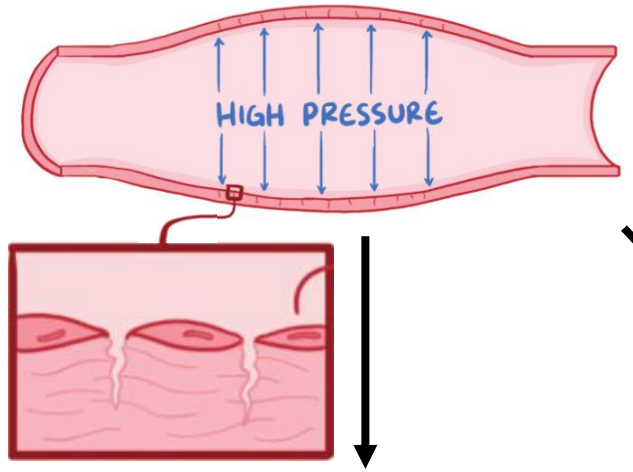
Identifiable Causes of Hypertension

- Renovascular disease
- Primary aldosteronism
- Sleep apnea
- Chronic kidney disease
- Drug-induced or related causes
- Chronic steroid therapy and Cushing's syndrome
- Thyroid or parathyroid
- Rare Monogenic inherited causes (Liddle, Gordon, AME, GRA, etc)
- Coarctation of the aorta
- Pheochromocytoma

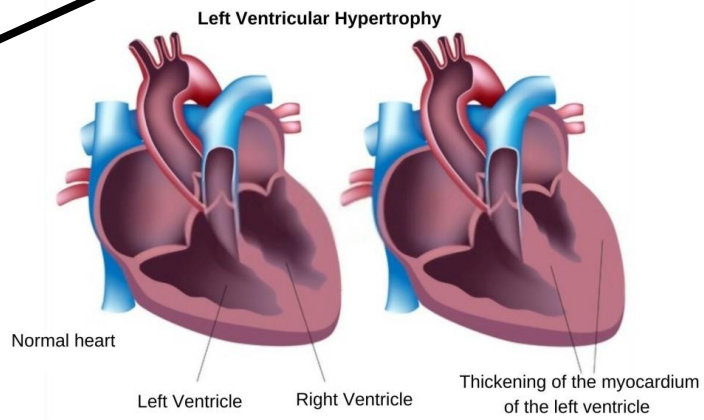
Hypertensive Target Organ Damage (TOD)

Stroke & Dementia



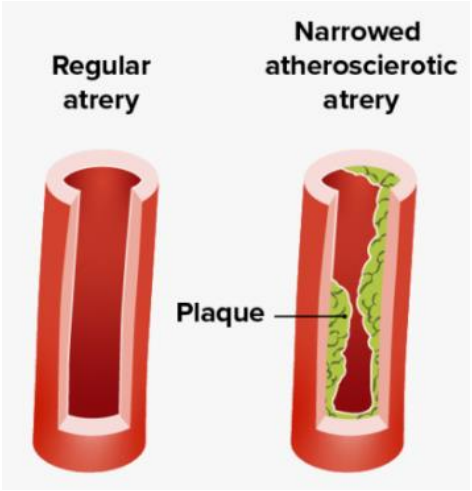


CVD

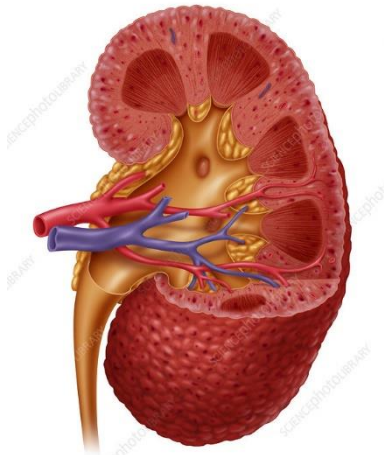


Retinopathy

PVD



Nephropathy



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Adult versus childhood HTN: Comparables

Adult Hypertension

- Leading cause of cardiovascular morbidity and mortality
- Leading Cause of Stroke and dementia in elderly
- Leading cause of advancing CKD and ESKD
- Leading cause of vasculopathy (PVD)
- Major cause of impotence and ED

Pediatric Hypertension

- LVH in many children. Early MACE in young adults with AHOY
- Neurocognitive alterations and changes in cerebral blood flow
- Youth with HTN & CKD progress much faster than normotensive children
- Alterations in PWV evident in AHOY
- Not studied in children and unlikely

Home BP Monitoring

Table 10. Procedures for Use of HBPM (8-10)

Patient training should occur under medical supervision, including:

- Information about hypertension
- Selection of equipment
- Acknowledgment that individual BP readings may vary substantially
- Interpretation of results

Devices:

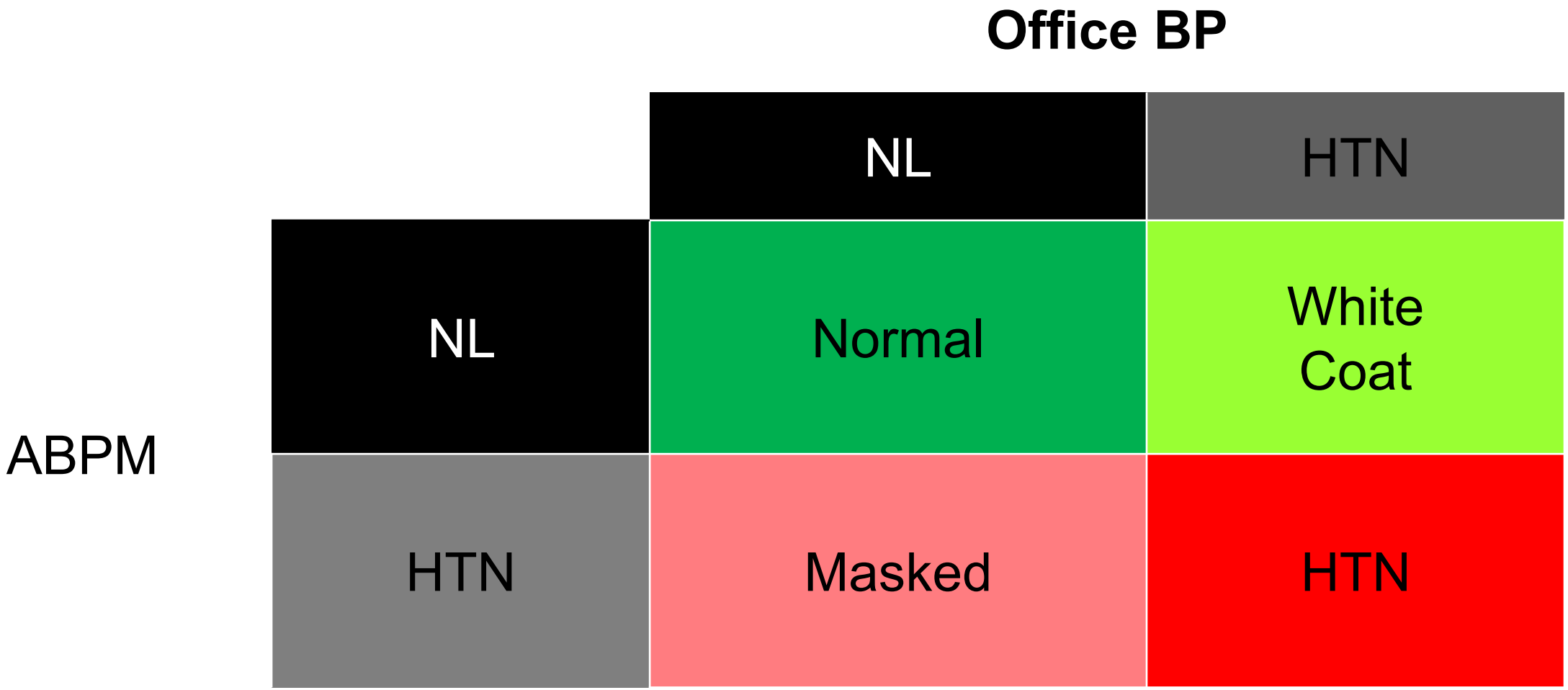
- Verify use of automated validated devices. Use of auscultatory devices (mercury, aneroid, or other) is not generally useful for HBPM because patients rarely master the technique required for measurement of BP with auscultatory devices.
- Monitors with provision for storage of readings in memory are preferred.
- Verify use of appropriate cuff size to fit the arm (Table 9).
- Verify that left/right inter-arm differences are insignificant. If differences are significant, instruct patient to measure BPs in the arm with higher readings.

Instructions on HBPM procedures:

- **Remain still:**
  - Avoid smoking, caffeinated beverages, or exercise within 30 min before BP measurements.
  - Ensure ≥5 min of quiet rest before BP measurements.
- **Sit correctly:**
  - Sit with back straight and supported (on a straight-backed dining chair, for example, rather than a sofa).
  - Sit with feet flat on the floor and legs uncrossed.
  - Keep arm supported on a flat surface (such as a table), with the upper arm at heart level.
- Bottom of the cuff should be placed directly above the antecubital fossa (bend of the elbow).
- **Take multiple readings:**
  - Take at least 2 readings 1 min apart in morning before taking medications and in evening before supper. Optimally, measure and record BP daily. Ideally, obtain weekly BP readings beginning 2 weeks after a change in the treatment regimen and during the week before a clinic visit.
- **Record all readings accurately:**
  - Monitors with built-in memory should be brought to all clinic appointments.
  - BP should be based on an average of readings on ≥2 occasions for clinical decision making.

BP Category (see Table 3)	BP Screening Schedule	Lifestyle Counseling (Weight, Nutrition)	Check Upper and Lower Extremity BP	ABPM	Diagnostic Evaluation	Initiate Treatment	Consider Sub-specialty Referral
Normal	Annual	X					
Elevated BP	Initial measurement	X					
	Second measurement: Repeat in 6 months	X	X				
	Third measurement: Repeat in 6 months	X		X	X		X
Stage 1 HTN	Initial measurement	X					
	Second measurement: Repeat in 1-2 weeks	X	X				
	Third measurement: Repeat in 3 months	X		X	X	X	X
Stage 2 HTN	Initial measurement	X	X				
	Second measurement: Repeat/refer to specialty care within 1 week	X		X	X	X	X

Combining Clinic and ABPM Status



Target-Organ Abnormalities in Children with Primary Hypertension

- LVH is the most studied target-organ damage.
- Also Identified
  - Subtle neurocognitive changes
  - Alterations in pulse wave velocity
  - Altered cerebral blood flow

Hypertensive TOD in Children

- Left ventricular hypertrophy
- Many studies have shown that LVH occurs commonly in hypertensive children:

  Zahka, 1981: LV mass 45% greater in teens with mild HTN compared to normotensives

  Daniels, 1990: 38% of teens with BP >90th percentile had LV mass >95th percentile

  Hanevold, 2004: 30% of patients from IPHA centers had LVH

  Brady, 2008: 41% LVH prevalence at initial evaluation for HTN

Hypertensive TOD in Children

- Increased carotid IMT
- Lande et al, *Hypertension.* 2006: Study of 28 children who underwent echocardiograms, ABPM and carotid US
- Carotid US also done in age- and BMI-matched controls

  Median cIMT of hypertensive subjects was greater than that of matched controls (0.67 vs 0.63 mm; *P*=0.045)

  cIMT was correlated with ambulatory BP parameters, especially daytime SBP index

  LV mass index did not correlate with cIMT

  Study suggests that cIMT is increased in childhood primary hypertension, independent of the effects of obesity

Despite TOD, linking childhood HTN to cardiovascular mortality requires a leap of faith

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USPTF states “no recommendation possible”

- I Recommendation (insufficient data)

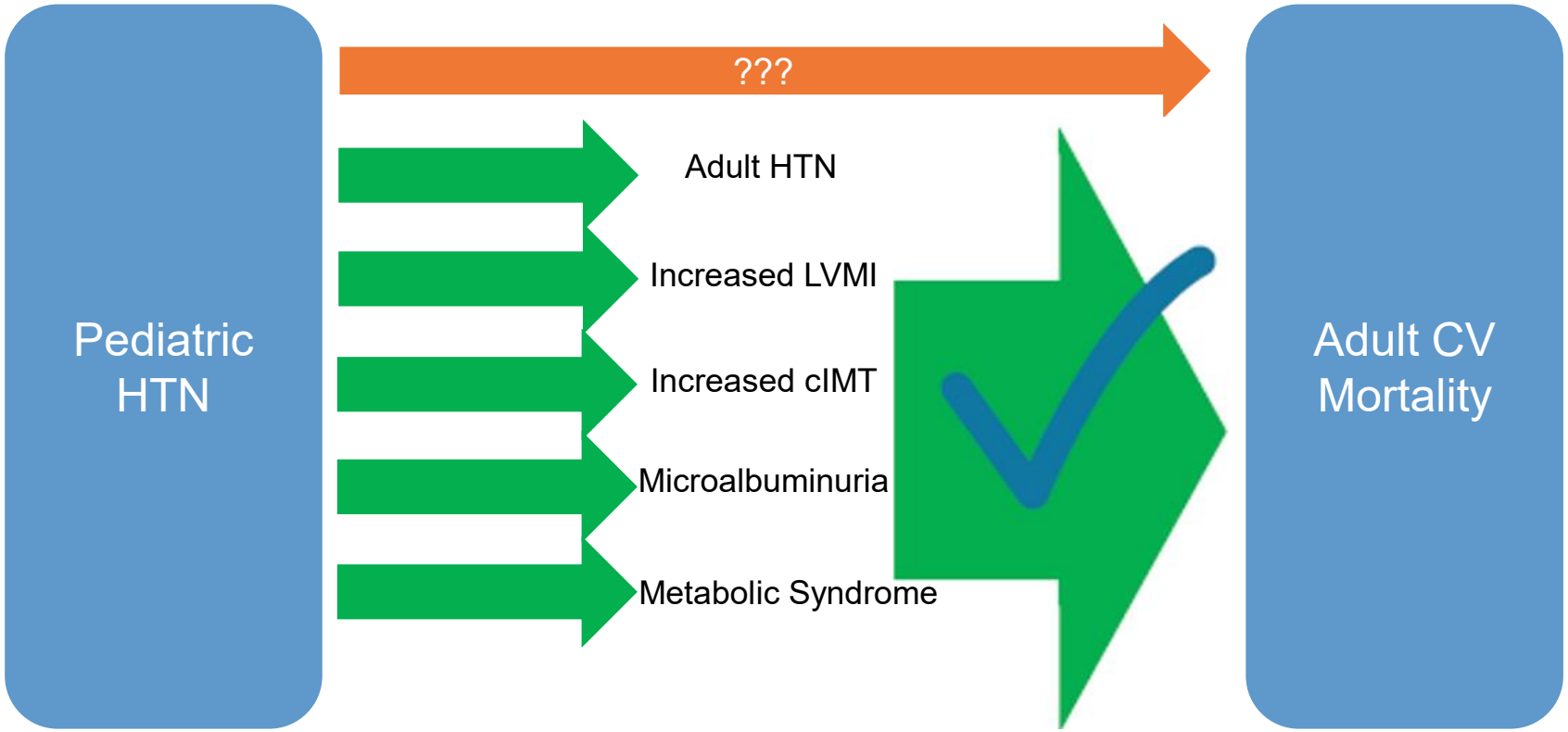
  “The benefits and harms of screening for high BP in children and adolescents are uncertain, and the balance of the benefits and harm cannot be determined”

USPTF is not asking the correct question…

Pediatric HTN → ??? → Adult CV Mortality

"paper or plastic?"

Linking childhood HTN to cardiovascular mortality requires a *small* leap of faith



Age-Specific Global Prevalence of Childhood Hypertension from 2000-2024

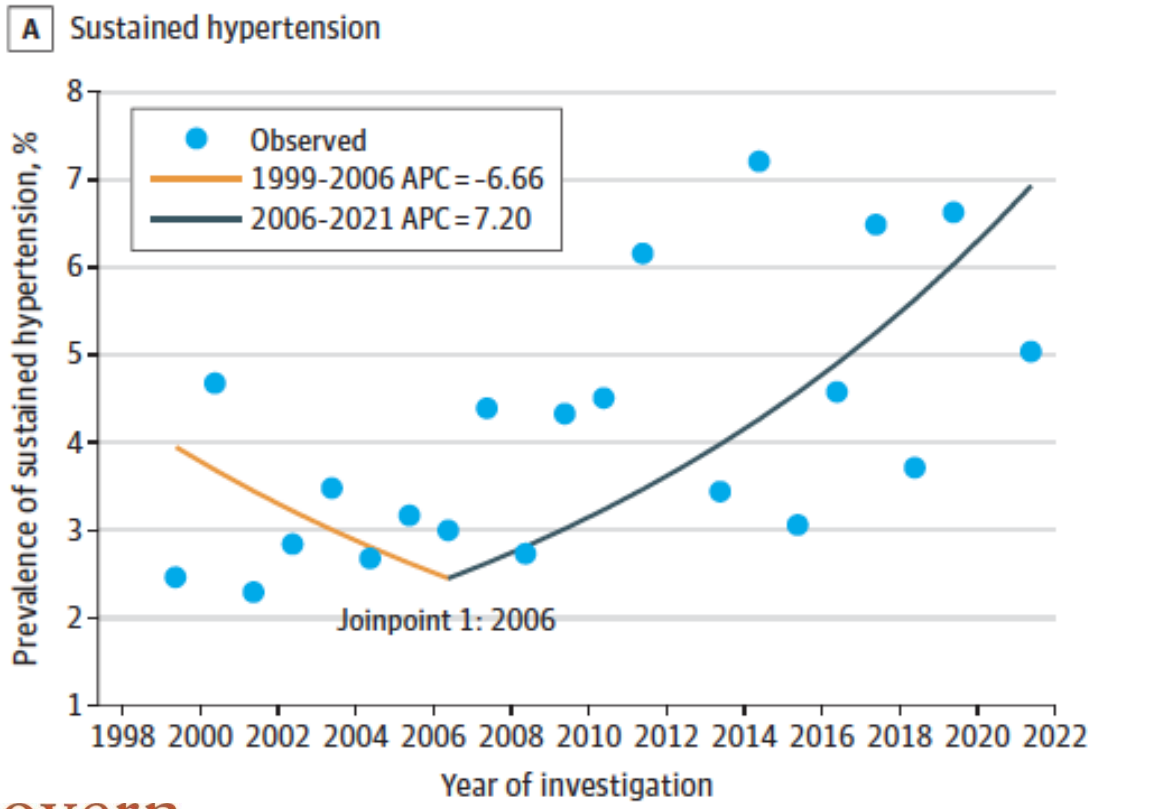
JAMA Pediatrics | Original Investigation

Global Prevalence of Hypertension in Children and Adolescents Younger Than 19 Years

A Systematic Review and Meta-Analysis

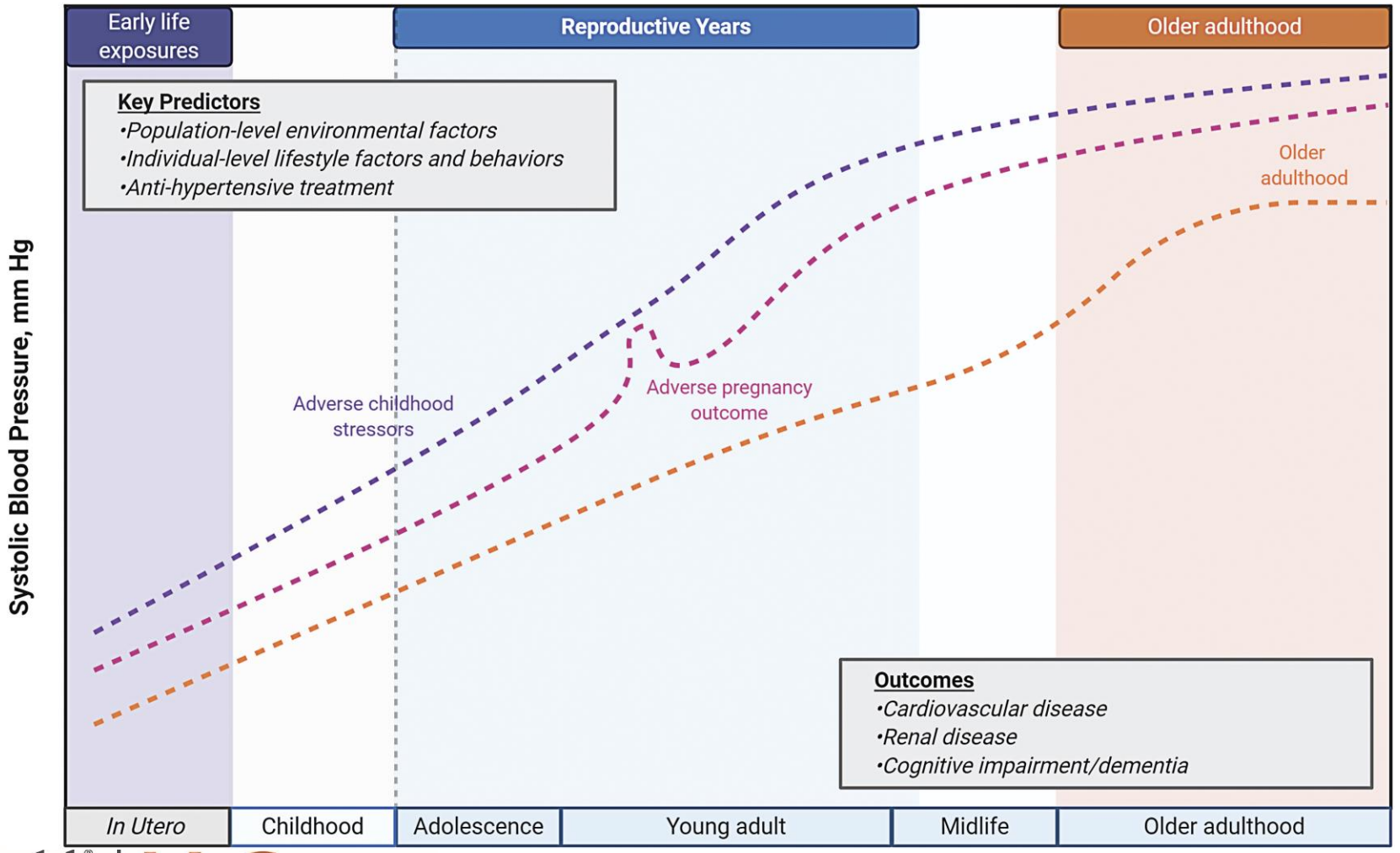
Figure 2. Pooled Prevalenc

Outcome of interest	I^2, %	Q test P value
Sustained hypertension	99.1	<.001
Stage 1 hypertension	98.7	<.001
Stage 2 hypertension	91.0	<.001
EBP	98.6	<.001
Occasional hypertension	99.8	<.001
Stage 1 hypertension	99.5	<.001
Stage 2 hypertension	98.4	<.001
EBP	99.5	<.001



JAMA Pediatrics Published online July 28, 2025

BP tracking from childhood to adulthood



Allen *Am J Hypertension* 2021

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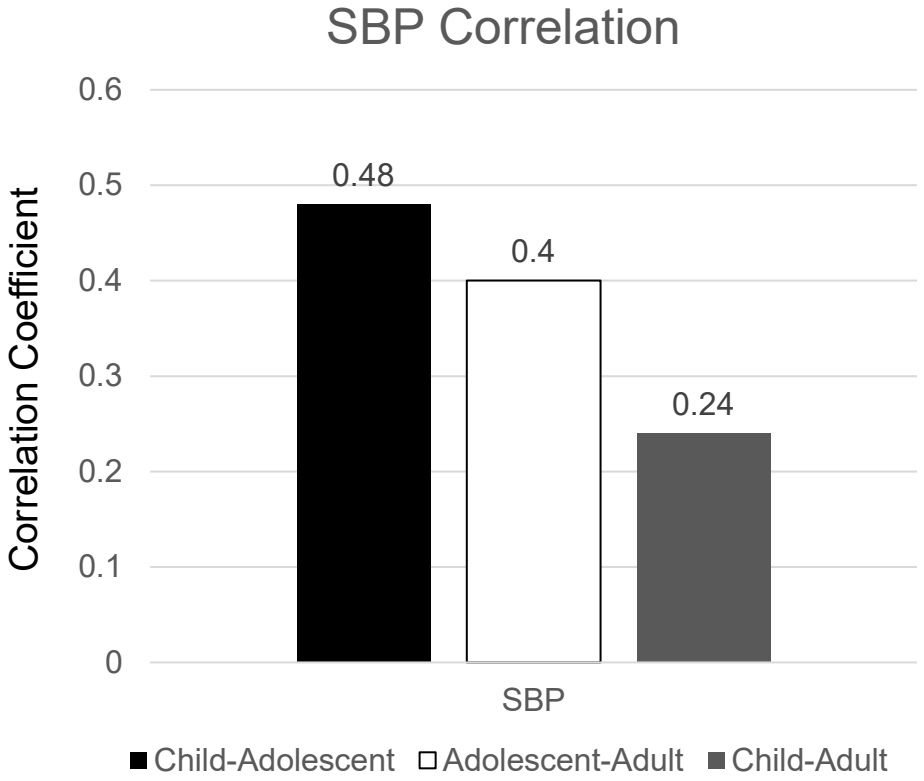
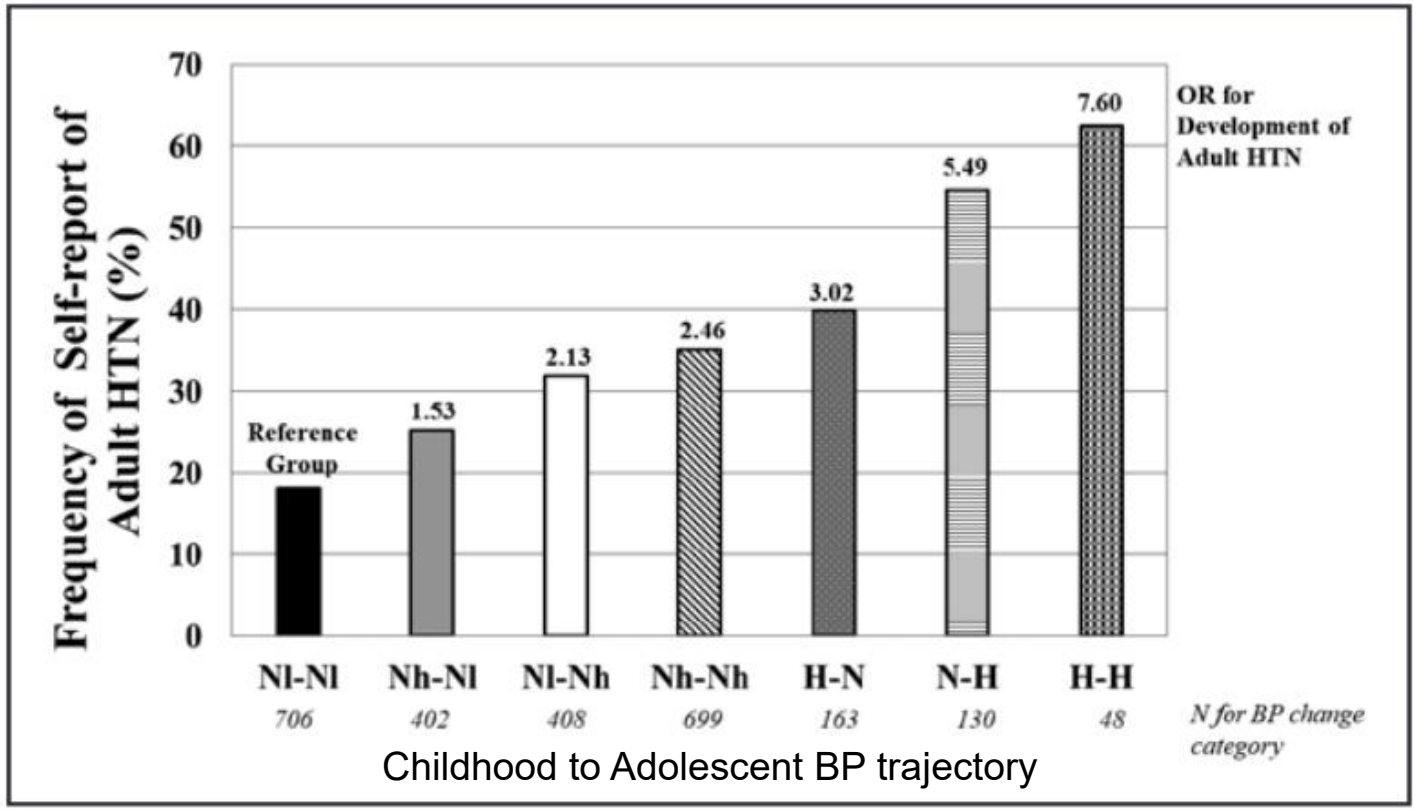
Childhood BP predicts adult hypertension

- I3C Consortium data





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Urbina *Hypertension* (2019)

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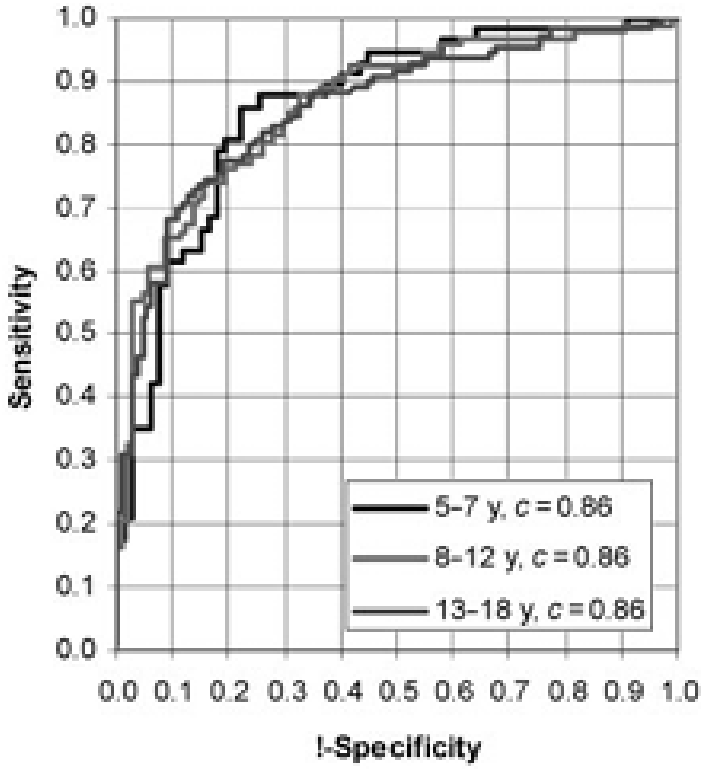
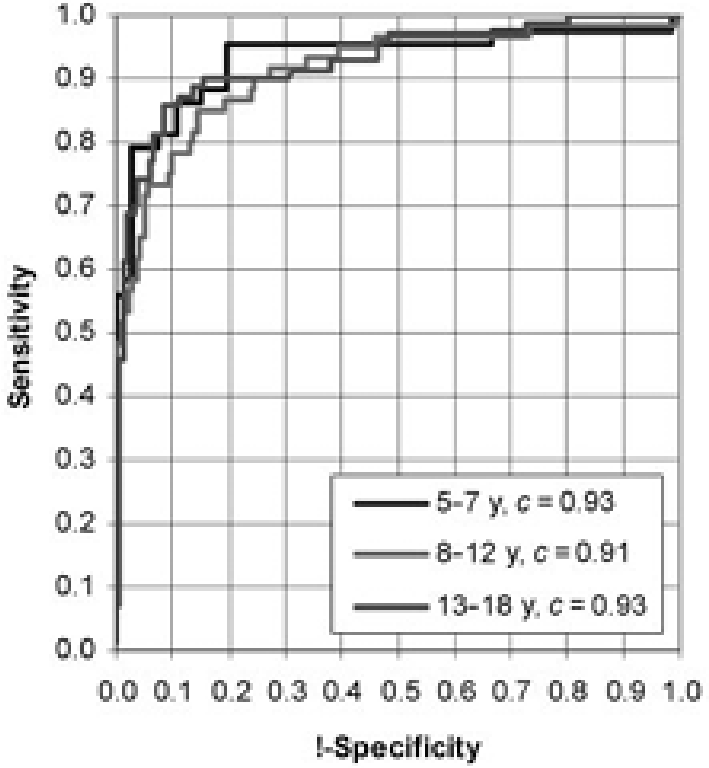
Childhood BP predicts adult hypertension

- Fels Longitudinal Study



Boys



Girls

TABLE 5 **Odds Ratios for Hypertension and Metabolic Syndrome at ≥30 Years of Age (Adjusted for Adult Age and Childhood BMI), Given a Systolic Blood Pressure Exceeding Criterion Values at a Single Examination in Childhood**

EBP (Yes/No)	Odds Ratio (95% Confidence Interval)	
	Male	Female
Hypertension		
5–7 y	3.8 (1.5–9.7)[a]	4.5 (1.1–17.7)[a]
8–13 y	3.5 (1.5–8.3)[a]	2.7 (1.0–7.1)[a]
14–18 y	1.1 (0.5–2.4)	3.8 (1.2–12.7)[a]

Sun *Pediatrics* (2007)

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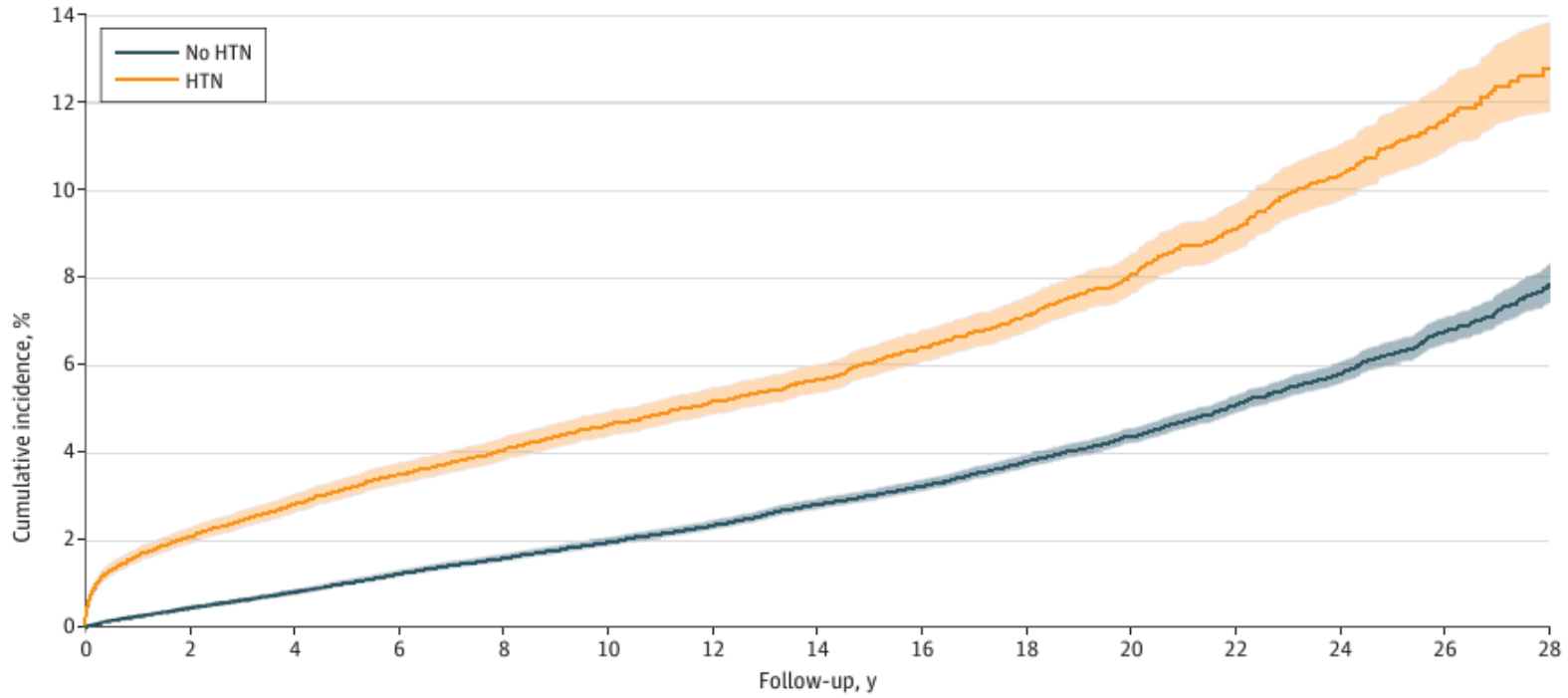
Major Cardiovascular Events among hypertensive children

- Population based retrospective study of Canadian children

Figure 1. Cumulative Probability of Major Adverse Cardiac Events (MACE) Among Children Diagnosed With Hypertension (HTN) vs Controls Without HTN



No. at risk															
HTN	25605	24006	21895	19889	17972	15900	13792	11597	9508	7470	5554	3914	2609	1479	387
No HTN	128025	122829	112805	103413	94049	83819	72622	60483	49149	38359	28266	20002	13437	7505	1953

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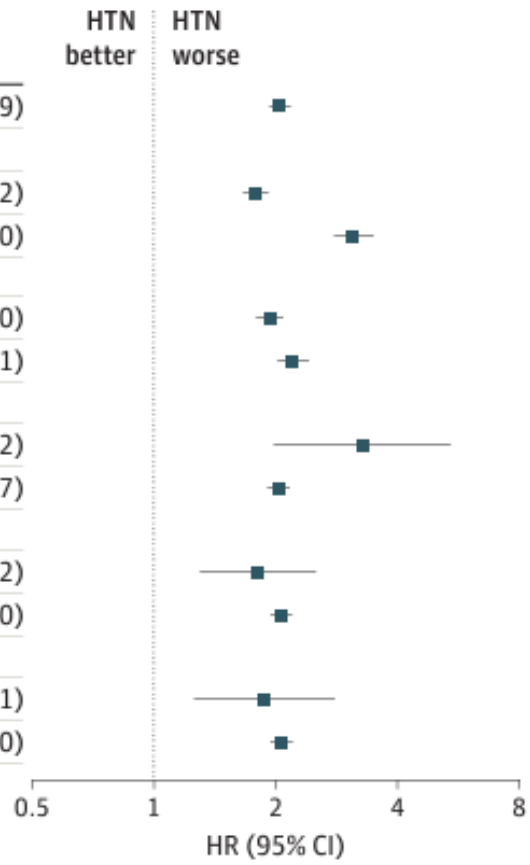
Major Cardiovascular Events among hypertensive children

- Population based retrospective study of Canadian children

Subgroup	Patients, No. (%)	MACE, % HTN	MACE, % Controls	HR (95% CI)	P value for interaction
Overall	153 630 (100)	6.9	2.0	2.06 (1.94-2.19)	
Age at diagnosis, y					
≥ 13	107 057 (69.7)	6.1	3.5	1.79 (1.67-1.92)	<.001
<13	46 573 (30.3)	6.1	2.1	3.09 (2.80-3.50)	
Sex					
Male	88 458 (57.6)	5.6	3.0	1.94 (1.79-2.10)	.03
Female	65 172 (42.4)	6.7	3.1	2.21 (2.03-2.41)	
CKD					
Yes	2004 (1.3)	7.5	2.4	3.29 (1.99-5.42)	.06
No	151 626 (98.7)	6.1	3.1	2.05 (1.93-2.17)	
Diabetes					
Yes	2892 (1.9)	9.8	5.9	1.81 (1.30-2.52)	.33
No	150 738 (98.1)	6.0	3.0	2.07 (1.95-2.20)	
Cardiac surgery					
Yes	882 (0.6)	23.8	14.2	1.88 (1.26-2.81)	.69
No	152 748 (99.4)	6.0	3.0	2.07 (1.95-2.20)	



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Elevated BP in childhood → Adult CV Risk

Elevated Blood Pressure in Childhood or Adolescence and Cardiovascular Outcomes in Adulthood
A Systematic Review

Lili Yang, Costan G. Magnussen, Liu Yang, Pascal Bovet, Bo Xi

Elevated BP in childhood or adolescence was significantly associated with intermediate CVD markers (high PWV, high cIMT, and LVH) in adulthood

Elevated BP in childhood or adolescence, but normal BP in adulthood, did not have a significantly increased risk

Table 1. Meta-Analysis of the Associations Between BP in Childhood or Adolescence and Intermediate CVD Markers in Adulthood

Adult Outcomes	No. of Articles (No. of Participants)	OR	95% CI	I^2 (%)	$P_{heterogeneity}$
High PWV					
Elevated BP	3 (3725)	1.83	1.39–2.40	41.9	0.179
High cIMT					
Elevated BP	2 (4152)	1.60	1.29–2.00	0.0	0.630
Continuous SBP	2 (7177)	1.21	1.09–1.34	17.3	0.272
LVH					
Elevated BP	2 (3019)	1.40	1.20–1.64	0.0	0.652
Continuous SBP	2 (2317)	1.27	1.08–1.51	0.0	0.968
LV remodeling					
Concentric remodeling					
Continuous SBP	2 (2317)	1.24	1.09–1.41	0.0	0.651
Eccentric hypertrophy					
Continuous SBP	2 (2317)	1.19	0.97–1.45	0.0	0.546
Concentric hypertrophy					
Continuous SBP	2 (2317)	1.52	1.17–1.98	0.0	0.658

Yang *Hypertension* 2020; 75:948-955.

Benefits of Lowering BP in Adults

	Average Percent Reduction
Stroke incidence	35-40%
Myocardial infarction	25-50%
Heart Failure	50%

Treatment of hypertension in children & adolescents

KAS 20: Lifestyle Interventions

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At the time of diagnosis of elevated BP or HTN in a child or adolescent, clinicians should provide advice on the DASH diet and recommend moderate to vigorous activity at least 3 to 5 days per week (30-60 minutes per session) to help reduce BP.

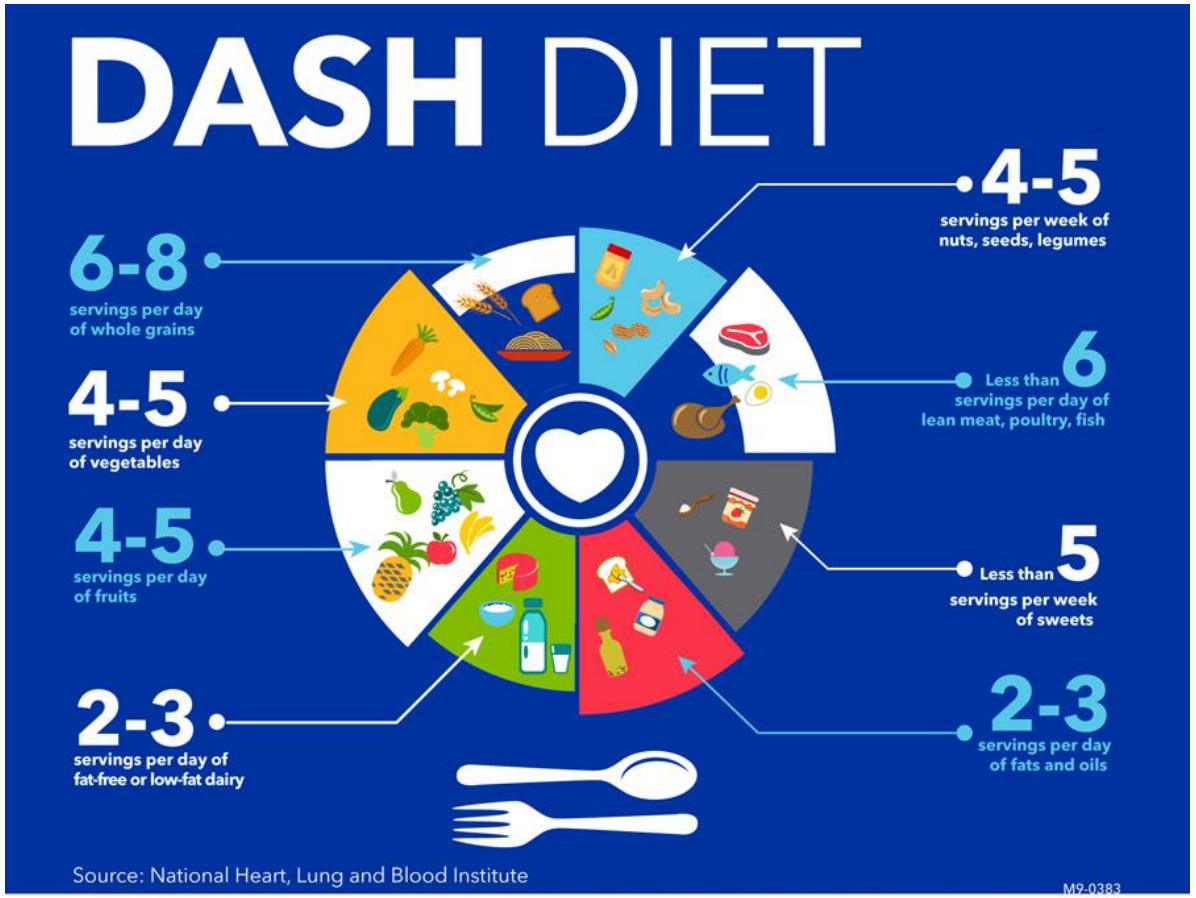
Flynn (2017) *Pediatrics* PMID: 28827377

Dietary Modification: First line therapy

- Limited dietary salt
- High in fresh fruits
- High in fresh vegetables
- High in low-fat dairy
- High in fiber

- Above all:

Avoid excess weight gain



The DASH diet (Dietary Approaches to Stop Hypertension) has been shown to help lower blood pressure and prevent heart disease, stroke, diabetes and even some forms of cancer. It focuses on eating more fresh fruits and vegetables.

This is a guide to how much of each food group you should eat every day, based on eating 2,000 calories per day.

Lifestyle Modification

Table 9. Lifestyle modifications to prevent and manage hypertension*

Modification	Recommendation	Approximate SBP Reduction (Range)†
Weight reduction	Maintain normal body weight (body mass index 18.5–24.9 kg/m²).	5–20 mmHg/10kg[92,93]
Adopt DASH eating plan	Consume a diet rich in fruits, vegetables, and lowfat dairy products with a reduced content of saturated and total fat.	8–14 mmHg[94,95]
Dietary sodium reduction	Reduce dietary sodium intake to no more than 100 mmol per day (2.4 g sodium or 6 g sodium chloride).	2–8 mmHg[94-96]
Physical activity	Engage in regular aerobic physical activity such as brisk walking (at least 30 min per day, most days of the week).	4–9 mmHg[97-98]
Moderation of alcohol consumption	Limit consumption to no more than 2 drinks (e.g., 24 oz beer, 10 oz wine, or 3 oz 80-proof whiskey) per day in most men, and to no more than 1 drink per day in women and lighter weight persons.	2–4 mmHg[99]

Pharmacologic management of Primary HTN

- Start with the ABCDE
  - ACEi/ARB
  - β-blockers
  - CCB
  - Diuretics
  - Everything Else

Clinical management of chronic hypertension

1. Therapeutic lifestyle initiatives
2. Start A-C-D* (Consider special populations)
3. Add until on all 3 (A-C-D)
4. Add a β blocker (A-B-C-D)
5. If resistant hypertension, move on to other (E) options
    1. BP still uncontrolled on adequate doses of at least 3 antihypertensives (including a diuretic)
    2. Beyond ABCD…we'll see what Dr. Flynn has to say next!

Key Action Statement 23

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- Children or adolescents with both CKD and HTN should be treated to lower 24-hour MAP to <50th percentile by ABPM

Flynn et al. *Pediatrics* 2017 PMID: 28827377

Benefits of BP lowering in children with CKD

- Both the ESCAPE trial in Europe and the CKiD cohort study in USA have shown that intensive BP control can slow the progression of chronic kidney disease in children and young adults

- BP management in CKD is beyond the scope of today's lecture, but if you are interested, we have fellowship spots open now!

Lots of antihypertensives out there…

Class	Drug (Trade Name)	Usual Dose Range mg/Day	Usual Daily Frequency*
Thiazide diuretics	chlorothiazide (Diuril)	125–500	1–2
	chlorthalidone (generic)	12.5–25	1
	hydrochlorothiazide (Microzide, HydroDIURIL†)	12.5–50	1
	polythiazide (Renese)	2–4	1
	indapamide (Lozol†)	1.25–2.5	1
	metolazone (Mykrox)	0.5–1.0	1
	metolazone (Zaroxolyn)	2.5–5	1
Loop diuretics	bumetanide (Bumex†)	0.5–2	2
	furosemide (Lasix†)	20–80	2
	torsemide (Demadex†)	2.5–10	1
Potassium-sparing diuretics	amiloride (Midamor†)	5–10	1–2
	triamterene (Dyrenium)	50–100	1–2
Aldosterone receptor blockers	eplerenone (Inspra)	50–100	1
	spironolactone (Aldactone†)	25–50	1
BBs	atenolol (Tenormin†)	25–100	1
	betaxolol (Kerlone†)	5–20	1
	bisoprolol (Zebeta†)	2.5–10	1
	metoprolol (Lopressor†)	50–100	1–2
	metoprolol extended release (Toprol XL)	50–100	1
	nadolol (Corgard†)	40–120	1
	propranolol (Inderal†)	40–160	2
	propranolol long-acting (Inderal LA†)	60–180	1

BP Lowering effect of pharmacology

		None	Losartan		Lisinopril		Metoprolol	
Hydrochlorothiazide	Amlodipine	0 mg	50 mg	100 mg	10 mg	20 mg	50 mg	100 mg
0 mg	0 mg		7 (6–8)	8 (7–9)	7 (6–8)	10 (7–11)	7 (5–8)	7 (6–8)
0 mg	5 mg	9 (8–10)	15 (13–16)	16 (14–17)	15 (13–16)	18 (15–19)	15 (13–16)	15 (14–17)
0 mg	10 mg	12 (10–15)	18 (15–19)	19 (16–21)	18 (16–20)	21 (17–22)	18 (16–20)	18 (16–21)
12·5 mg	0 mg	6 (5–7)	12 (11–13)	13 (12–14)	12 (11–13)	15 (13–16)	12 (11–13)	12 (11–14)
12·5 mg	5 mg	14 (13–15)	19 (17–20)	20 (18–21)	20 (18–21)	22 (19–24)	19 (17–21)	20 (17–21)
12·5 mg	10 mg	17 (15–19)	22 (19–24)	23 (20–25)	22 (20–24)	25 (21–27)	22 (19–24)	22 (19–24)
25 mg	0 mg	8 (7–9)	14 (12–15)	15 (13–16)	14 (12–15)	17 (15–18)	14 (12–15)	14 (12–15)
25 mg	5 mg	16 (14–17)	21 (19–22)	22 (19–23)	21 (19–22)	24 (21–25)	21 (19–22)	21 (18–23)
25 mg	10 mg	19 (17–21)	23 (20–25)	24 (21–26)	24 (21–25)	26 (22–28)	23 (20–25)	23 (20–25)

Efficacy

Low intensity | Moderate intensity | High intensity

Wang *The Lancet*, 2025.

Fixed dose combinations, when feasible

Combinations	Fixed Dose examples
ARB-Diuretic	Irbesartan/HCTZ Losartan/HCTZ Telmisartan/HCTZ Valsartan/HCTZ
ACEi-Diuretic	Captopril/HCTZ Enalapril/HCTZ Lisinopril/HCTZ Moexipril/HCTZ
ACEi-CCB	Benazepril/Amlodipine Trandolapril/Verapamil
ARB-CCB	Amlodipine/Olmesartan Amlodipine/Valsartan Amlodipine/Telmisartan
B-blocker-Diuretic	Atenolol/chlorthalidone Metoprolol/HCTZ Propranolol/HCTZ
ARB-ACEi	Telmisartan/Ramipril (DON'T USE)
Centrally acting agents-Diuretics	Clonidine/Chlorthalidone

Triple Drug Combo	Examples
CCB-ARB-Diuretic	Amlodipine/Valsartan/HCTZ Amlodipine/Olmesartan/HCTZ
CCB-DRI-Diuretic	Amlodipine/Aliskirin/HCTZ

Newer classes of therapeutics

- SGLT-2 inhibitors

  Empaglifozin, Canaglifozin, Dapaglifozin

  Direct diuretic action & weight loss

- GLP-1 agonists

  Semaglutide, Tirzepatide, Dulaglutide, Liraglutide

  Direct vasodilation, RAAS inhibition, Natriuresis, Sympathetics

- Bariatric surgery

Hypertension in Youth: Similarities

- Same biology
  - Salt sensitivity
  - Chronic Kidney disease
  - Cardiovascular damage and risk
    - LVH
    - PWV
    - MACE data

Hypertension in Youth: Differences

- Much fewer patients (subjects) to study compared to adult trials.
  - Especially true when only considering “resistant hypertension”
- Kids don’t have the same *immediate* risk that adults do
  - No study will show HARD outcomes in pediatric hypertension
  - Horizon for injury is too far
  - Studies will HAVE to rely on surrogate BP outcomes
- We do have *longitudinal* showing link between childhood hypertension and adult hypertension

Conclusions

- Alterations in the definition of hypertension in youth have changed the fundamental epidemiology of the disorder
  - Historically (140/90): Most had secondary hypertension
  - Modern (%ile based): Most have primary (essential) hypertension
- Rising prevalence of hypertension in youth makes this population especially important to screen and treat
- Established data show clear tracking of childhood blood pressure abnormalities into adulthood
- Emerging data show early MACE among young adults with a history of childhood onset hypertension