



Ente Ospedaliero Cantonale

Reference Values and Simplified Methods for Interpretation of Blood Pressure in Children and Adolescents

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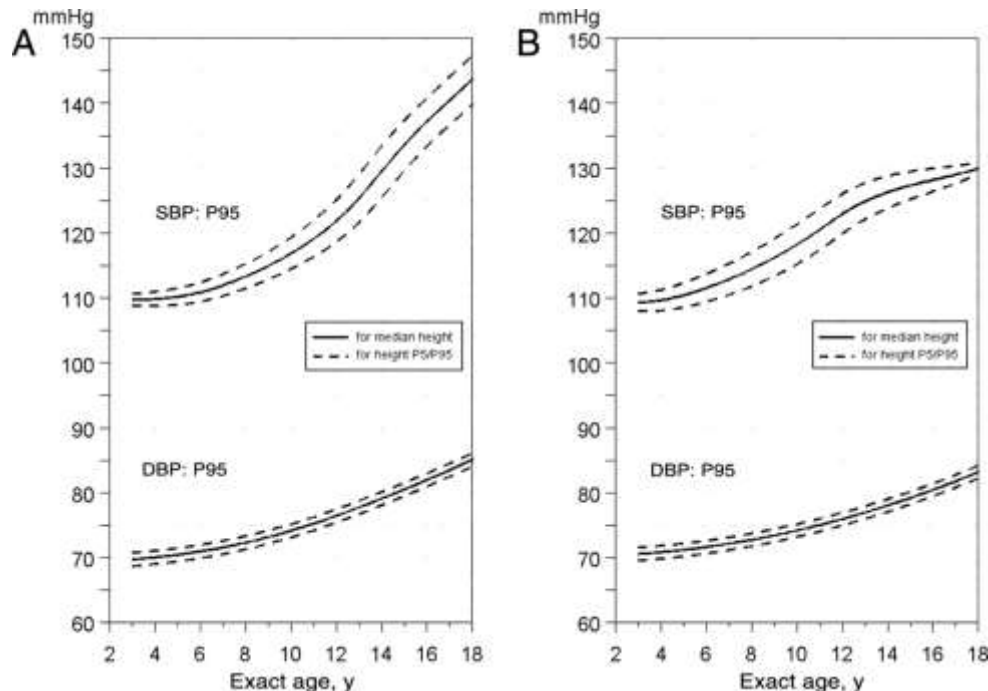


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No conflicts of interest to declare

Definition of high blood pressure

- Children: Statistical methods
- Adults: Outcome variables
- Sex-, age-, and height-specific cutoffs to assess 95th percentile



Neuhauser et al. Pediatrics 2011

Reference values

- Change over time and country
- “IV report” vs “new US guideline 2017” vs “ESH guideline 2016”
- Reference values for Office BP vs Home BP vs Ambulatory BP measurements
- Tables are “complicated”

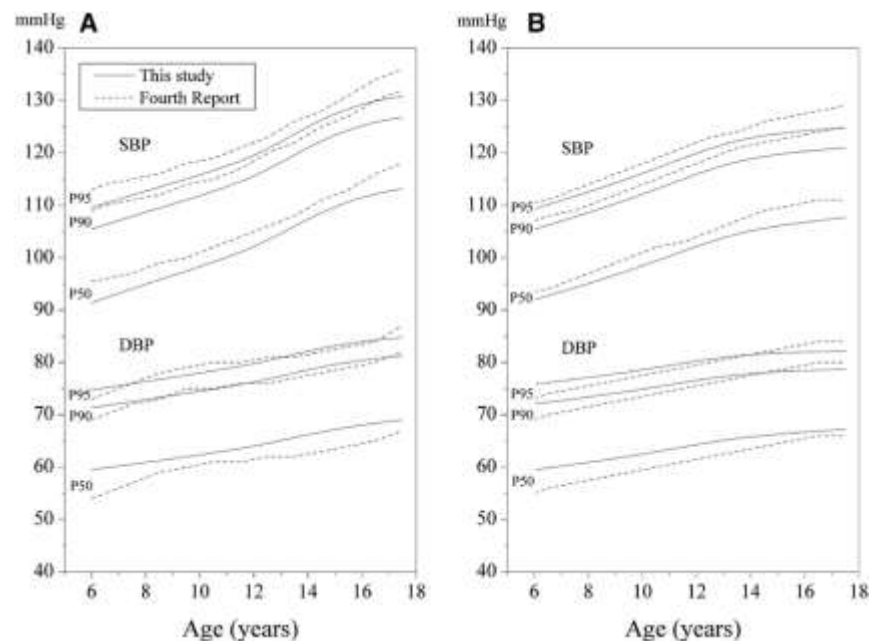
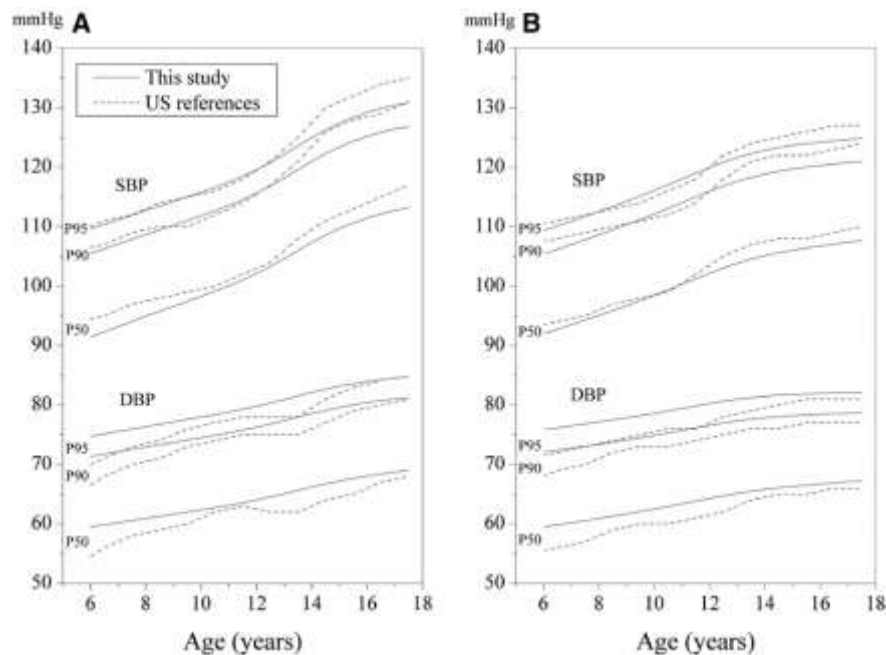
TABLE 4 BP Levels for Boys by Age and Height Percentile

Age (y)	BP Percentile	SBP (mmHg)						
		Height Percentile or Measured Height						
		5%	10%	25%	50%	75%	90%	95%
1	Height (in)	30.4	30.8	31.6	32.4	33.3	34.1	34.6
	Height (cm)	77.2	78.3	80.2	82.4	84.6	86.7	87.9
	50th	85	85	86	86	87	88	88
	90th	98	99	99	100	100	101	101
	95th	102	102	103	103	104	105	105
	95th + 12 mm Hg	114	114	115	115	116	117	117
2	Height (in)	35.9	34.4	35.3	36.3	37.3	38.2	38.8
	Height (cm)	86.1	87.4	89.6	92.1	94.7	97.1	98.5
	50th	87	87	88	89	89	90	91
	90th	100	100	101	102	103	103	104
	95th	104	105	105	106	107	107	108
	95th + 12 mm Hg	116	117	117	118	119	119	120
3	Height (in)	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
	50th	88	89	89	90	91	92	92
	90th	101	102	102	103	104	105	105
	95th	106	106	107	107	108	109	109

Flynn et al. Pediatrics 2017

Reference values

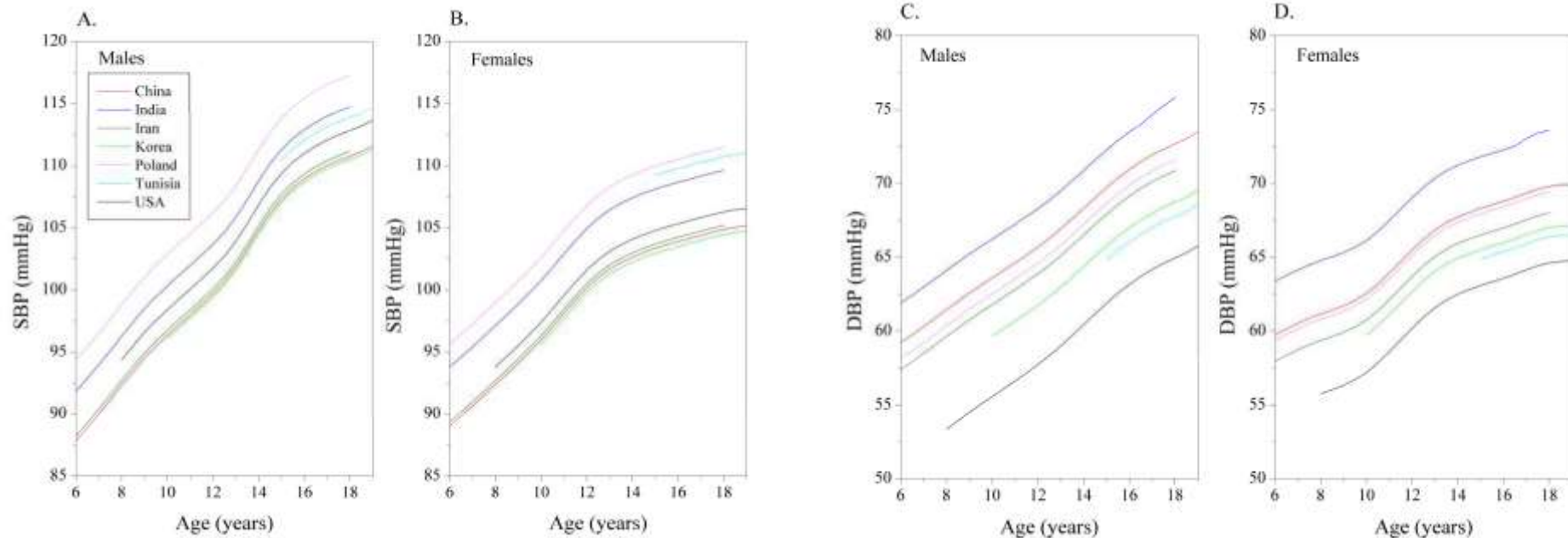
Comparison between **the international BP references** for nonoverweight children and adolescents and the **updated US BP references** for nonoverweight participants at median height.



Comparison between the **international BP references** for nonoverweight children and adolescents and the **US Fourth Report BP references** at median height.

Xi et al. Circulation 2016

Reference values

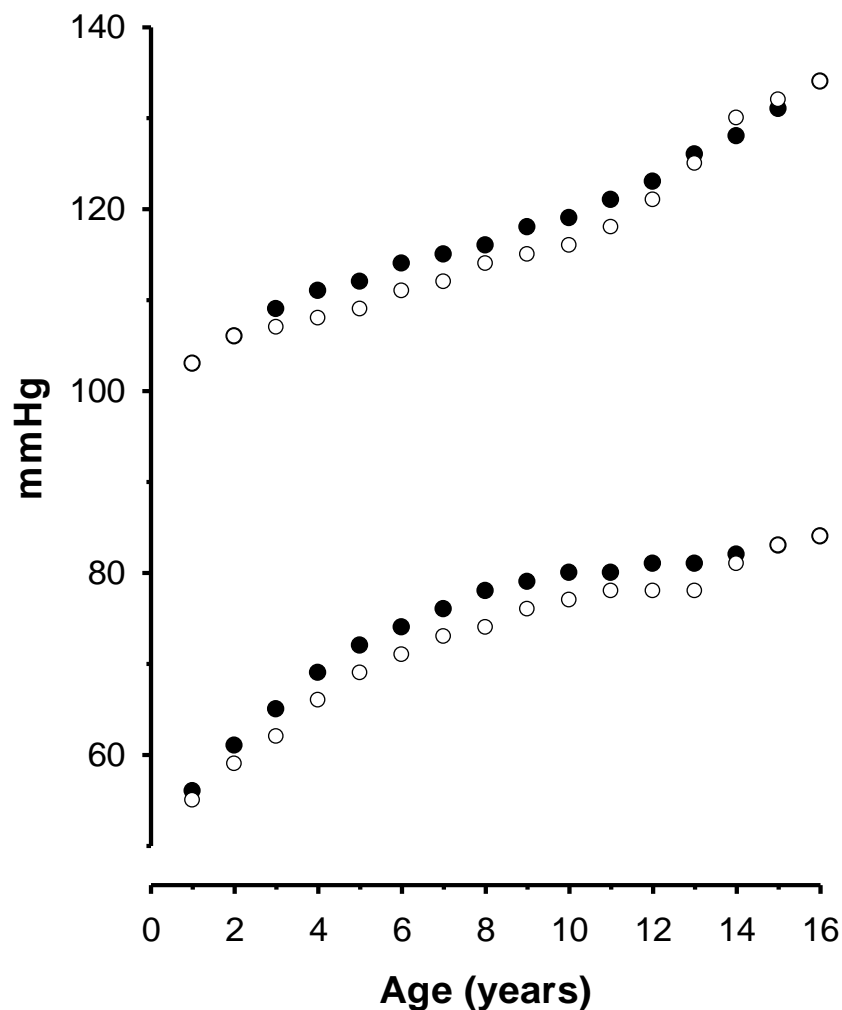


Median SBP (A. Males; B. Females) and DBP (C. Males; D. Females) at median height (derived from seven pooled data) by age and sex in seven nationally representative surveys of non-overweight children and adolescents

Xi et al. Circulation 2016

Reference values

Comparison between the IV report and the “new” reference values (US guidelines 2017), 95th percentile SBP and DBP at median height by age in boys



Complex and cumbersome decision process

- Diagnosis of hypertension commonly not made or inaccuracy in classification
- Only mentioned in 26% of more than 500 (pre)hypertensive children (Hansen)
- Strategies to improve correct diagnosis and recognition needed
- Development of easier tools to diagnose hypertension by simplified thresholds

Hansen et al. JAMA 2007

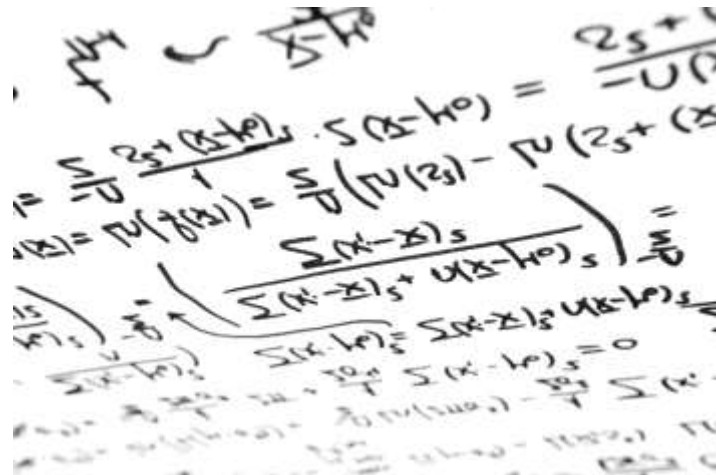
Question

Which methods do you use to diagnose hypertension?

- A. Original reference values
- B. Mathematical formulas
- C. Simplified tables
- D. BP to height ratio
- E. BP to absolute height
- F. Age-based thresholds
- G. Apps (smartphone, PC)

User-friendly tools - examples

- Mathematical formulas
- Simplified tables
- BP to height ratio
- BP to absolute height
- Age-based thresholds for prehypertension and hypertension



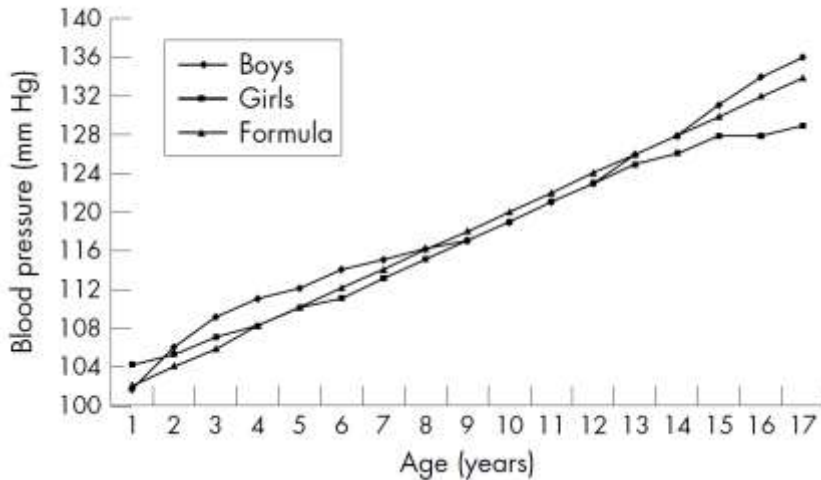
Tools to identify children with elevated blood pressure (BP)

Tool (references)	Issue
Simple equations relating BP thresholds to age (8,10)	It requires calculations at the point of care; their ability to identify children with elevated BP has to be determined.
Simple tables with few BP thresholds (9,11)	Multiple possible tables can be proposed and their ability to identify children with elevated BP has to be compared.
Blood pressure-to-height ratio (12-17)	It requires calculations at the point of care; the optimal cut-off points have to be established.

Chiolerio et al. Paediatr Child Health 2013

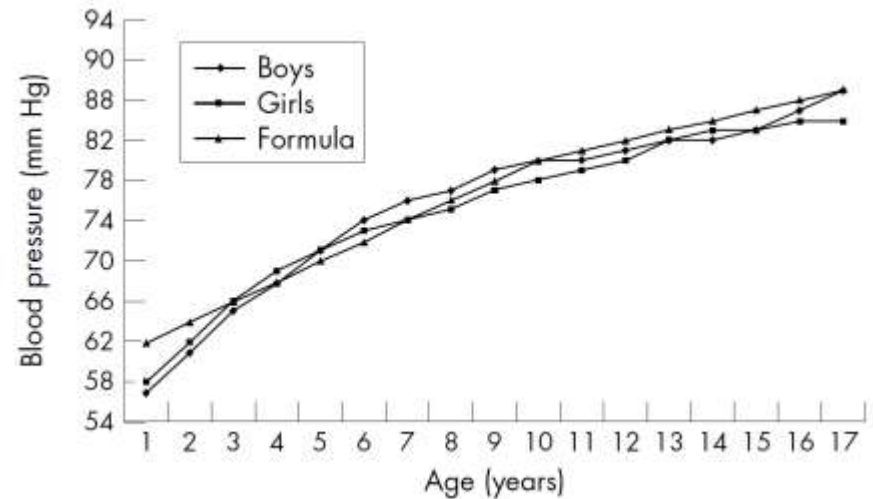
Example 1 - Somu

- 95th percentile of BP by 50th percentile of height



Systolic blood pressure (95th centile)

1–17 years = 100 + (age in years × 2)



Diastolic blood pressure (95th centile)

1–10 years = 60 + (age in years × 2)

11–17 years = 70 + (age in years).

Somu et al. Arch Dis Child 2003

Example 2 – simplified table

TABLE 6 Screening BP Values Requiring Further Evaluation

Age, y	BP, mm Hg			
	Boys		Girls	
	Systolic	DBP	Systolic	DBP
1	98	52	98	54
2	100	55	101	58
3	101	58	102	60
4	102	60	103	62
5	103	63	104	64
6	105	66	105	67
7	106	68	106	68
8	107	69	107	69
9	107	70	108	71
10	108	72	109	72
11	110	74	111	74
12	113	75	114	75
≥13	120	80	120	80

Age, y	SBP, mm Hg			DBP, mm Hg		
	P ₅ (H)	P ₅₀ (H)	P ₉₅ (H)	P ₅ (H)	P ₅₀ (H)	P ₉₅ (H)
3–5	104	107	110	63	65	67
6–8	108	111	115	72	74	76
9–11	113	117	120	76	77	79
12–14	119	123	126	78	80	82
15–17						
Boys	126	131	135	81	83	85
Girls	124	127	131	82	83	85

*Flynn et al. Pediatrics 2017
Ma et al. Hypertension 2016*

Example 3 – BP to height ratio

BP to height ratio to identify elevated blood pressure in children

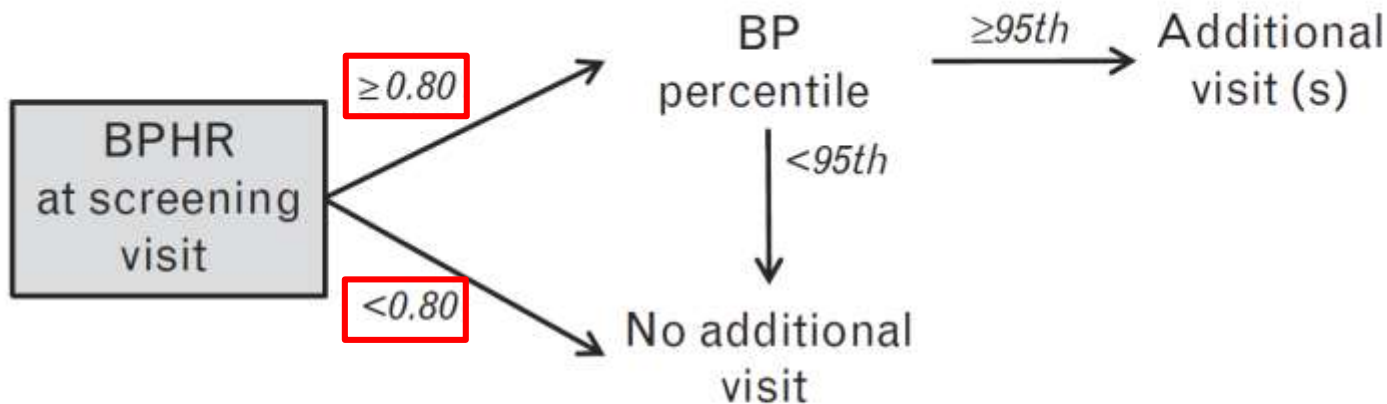
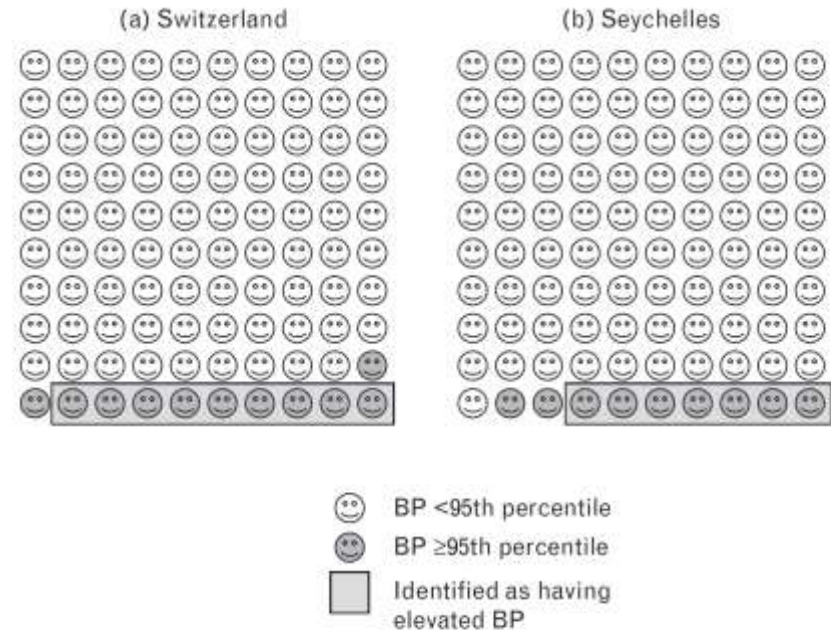


FIGURE 2 Use of systolic blood pressure-to-height ratio (BPHR) in the process of hypertension identification in children. If systolic BPHR is below 0.80, the schema is also applicable for diastolic BPHR, with a cutoff set at 0.45 (mmHg/cm).

Example 4 – BP to absolute height

Absolute height-specific thresholds to identify elevated blood pressure in children

Height category (cm)	Height range (cm)	SBP (mmHg)	DBP (mmHg)
80	<85	104	61
90	85–94	107	65
100	95–104	110	68
110	105–114	112	72
120	115–124	114	76
130	125–134	117	78
140	135–144	120	80
150	145–154	123	81
160	155–164	128	83
170	165–174	131	85
180	>175	136	87



Chiolerio et al. *J Hypertens* 2013

Performance of 11 simplified methods

- **When pooling individual data from the 7 countries, all 11 simplified methods performed well in screening high BP**
 - high AUC (0.84-0.98)
 - high sensitivity (0.69-1.00)
 - high specificity (0.87-1.00)
 - high NPV (≥ 0.98)

- **However: PPV low for most simplified methods**

Best methods

- **PPV reached about 0.90 for 3 methods**
 - sex- and age-specific BP references (at 95th percentile of height)
 - formula for BP references (at 95th percentile of height)
 - simplified method relying on a child's absolute height

Age, y	Boys						Girls					
	SBP, mm Hg			DBP, mm Hg			SBP, mm Hg			DBP, mm Hg		
	P ₅ (H)	P ₅₀ (H)	P ₉₅ (H)	P ₅ (H)	P ₅₀ (H)	P ₉₅ (H)	P ₅ (H)	P ₅₀ (H)	P ₉₅ (H)	P ₅ (H)	P ₅₀ (H)	P ₉₅ (H)
3	100	105	109	59	61	63	100	103	106	61	63	65
4	102	107	111	62	65	67	101	104	108	64	66	68
5	104	108	112	65	68	70	103	106	109	66	68	70
6	105	110	113	68	70	72	104	108	111	68	70	72
7	106	111	115	70	72	74	106	109	113	69	71	73
8	107	112	116	71	73	76	108	111	114	71	72	74
9	109	114	118	72	75	77	110	113	116	72	73	75
10	111	115	119	73	75	78	112	115	118	73	74	76
11	113	117	120	74	76	78	114	117	120	74	75	77
12	115	120	120	74	76	79	116	119	120	75	76	78
13	117	120	120	75	77	79	117	120	120	76	77	79
14	120	120	120	75	78	80	119	120	120	77	78	80
15	120	120	120	76	79	80	120	120	120	78	79	80
16	120	120	120	78	80	80	120	120	120	78	80	80
17	120	120	120	80	80	80	120	120	120	78	80	80

	Age, y	P ₉₅ (H)
SBP	3-9	103+1.6*age
	10-17	120
DBP	3-9	61+1.6*age
	10-17	80

Height categories (cm)	Height range (cm)	SBP, mmHg	DBP, mmHg
80	<85	99	57
90	85-94	103	61
100	95-104	106	64
110	105-114	108	68
120	115-124	110	71
130	125-134	113	74
140	135-144	116	76
150	145-154	120	80
160	155-164	120	80
170	165-174	120	80
180	≥175	120	80

Ma et al. Hypertension 2016

Limitations of simplified methods

- Clinicians should be aware of the limitations to use simplified methods
 - Age range
 - Comorbidity – overweight, obesity, low birth weight, prematurity

Prediction analysis of adult hypertension and subclinical cardiovascular outcomes with a simplified approach

Simplified definition

- **Prehypertension:** 110/70 for children (6-11 yo) and 120/80 mm Hg for adolescents (12-17 yo)
- **Hypertension:** 120/80 for children (6-11 yo) and 130/85 mm Hg for adolescents (12-17 yo)

→ **Performed similarly when compared with the traditional complex BP references in predicting:**

- adult hypertension
- subclinical CVD outcomes measured as arterial stiffness, subclinical atherosclerosis, and LVH (Bogalusa Heart Study)

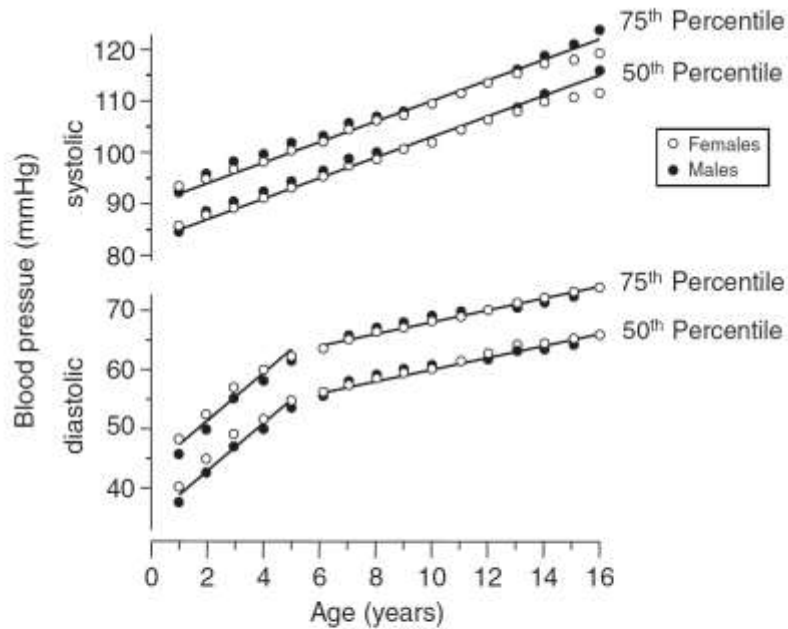
Software programs (apps)

- Supportive to easily calculate percentile
- Electronic health record-linked systems
- Improve recognition



Diagnosis vs goal of therapy

- Renal diseases (75th / 50th percentile)



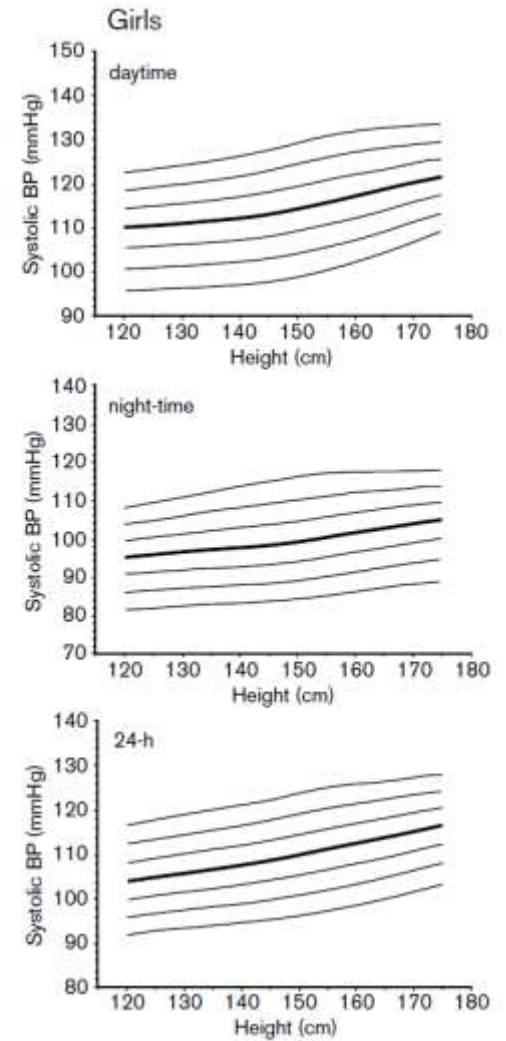
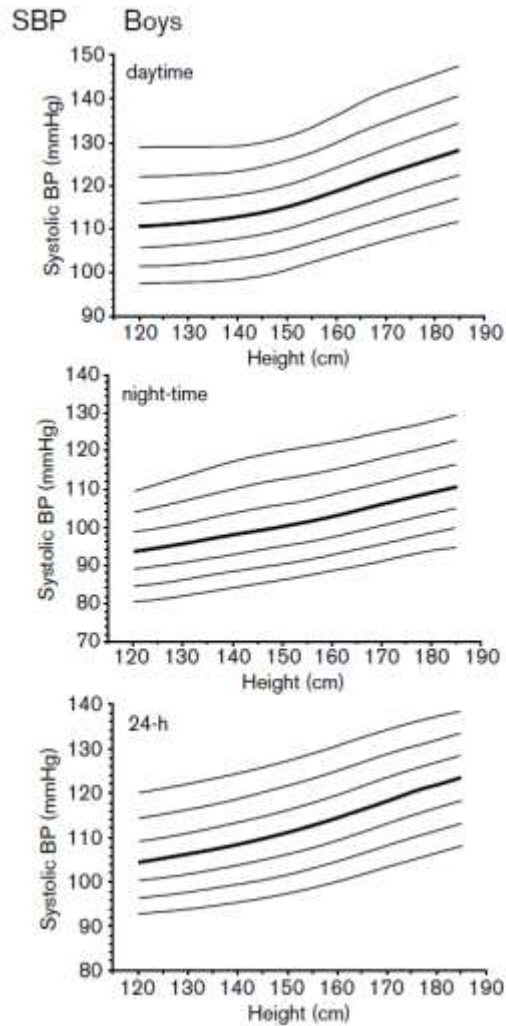
50th percentile	75th percentile
Systolic blood pressure 1–16 years: $83 + [\text{age (in years)} \times 2]$	Systolic blood pressure 1–16 years: $90 + [\text{age (in years)} \times 2]$
Diastolic blood pressure 1–5 years: $35 + [\text{age (in years)} \times 4]$ 6–16 years: $50 + [\text{age (in years)}]$	Diastolic blood pressure 1–5 years: $43 + [\text{age (in years)} \times 4]$ 6–16 years: $58 + [\text{age (in years)}]$

Fifth and 75th percentile blood pressure values corresponding to the 50th percentile for height. Full (men) and open (women) circles indicate blood pressure values of the task force. Lines indicate values calculated with the proposed formulae.

Simonetti et al. *J Hypertens* 2010

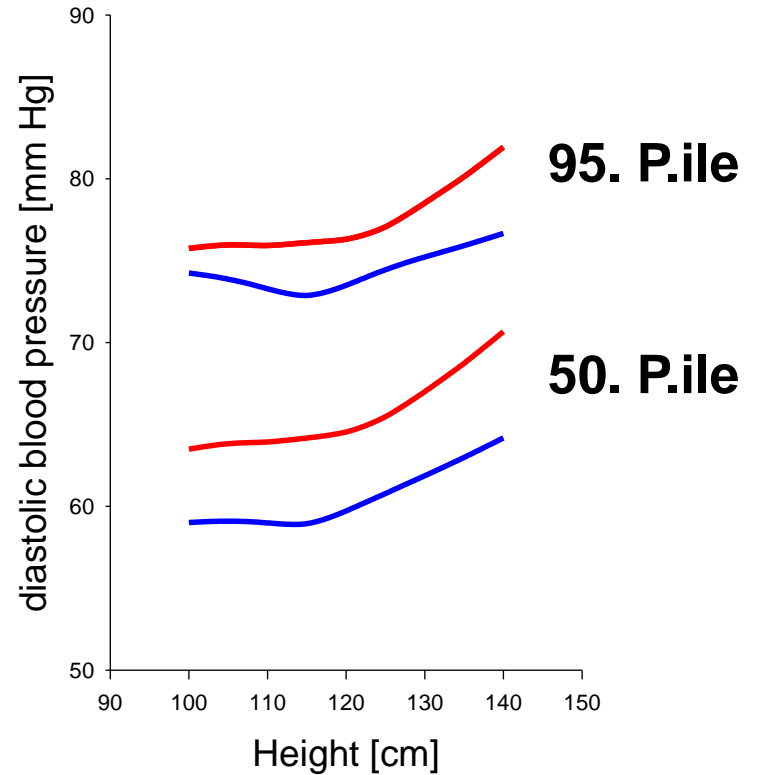
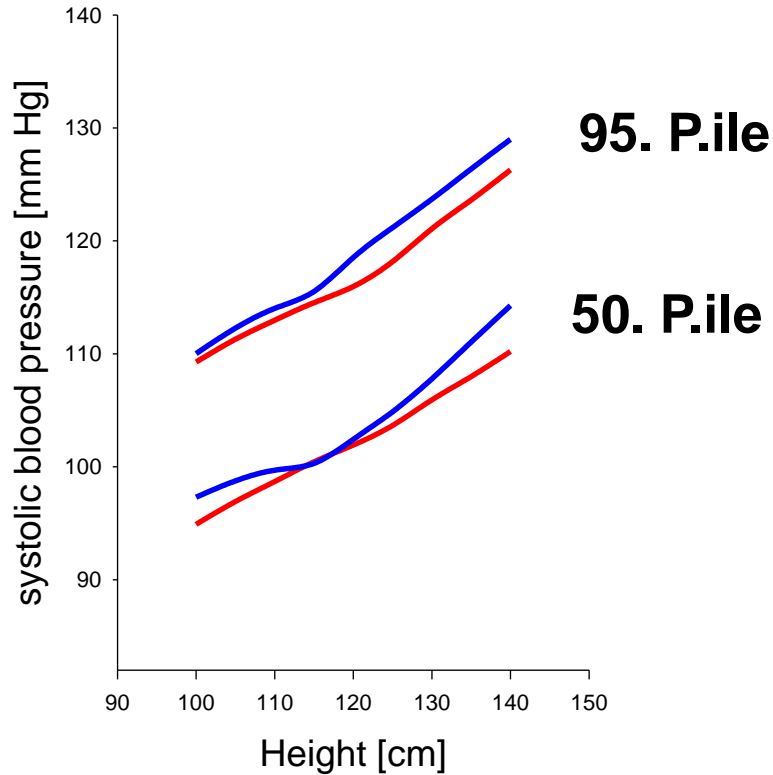
ABPM

- Reference values OK
- Device dependent (?)



Wühl et al. *J Hypertens* 2002

Oscillometric devices



BOSO medicus prestige



Omrom M5 professional



Unpublished data

New US guidelines 2017

- New reference values (non overweight children)
- User-friendly methods “obsolete” ?
- New user-friendly methods needed
- already included in guidelines

TABLE 6 Screening BP Values Requiring Further Evaluation

Age, y	BP, mm Hg			
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12	113	75	114	75
≥13	120	80	120	80

Flynn et al. Pediatrics 2017

New US guidelines 2017 - formula

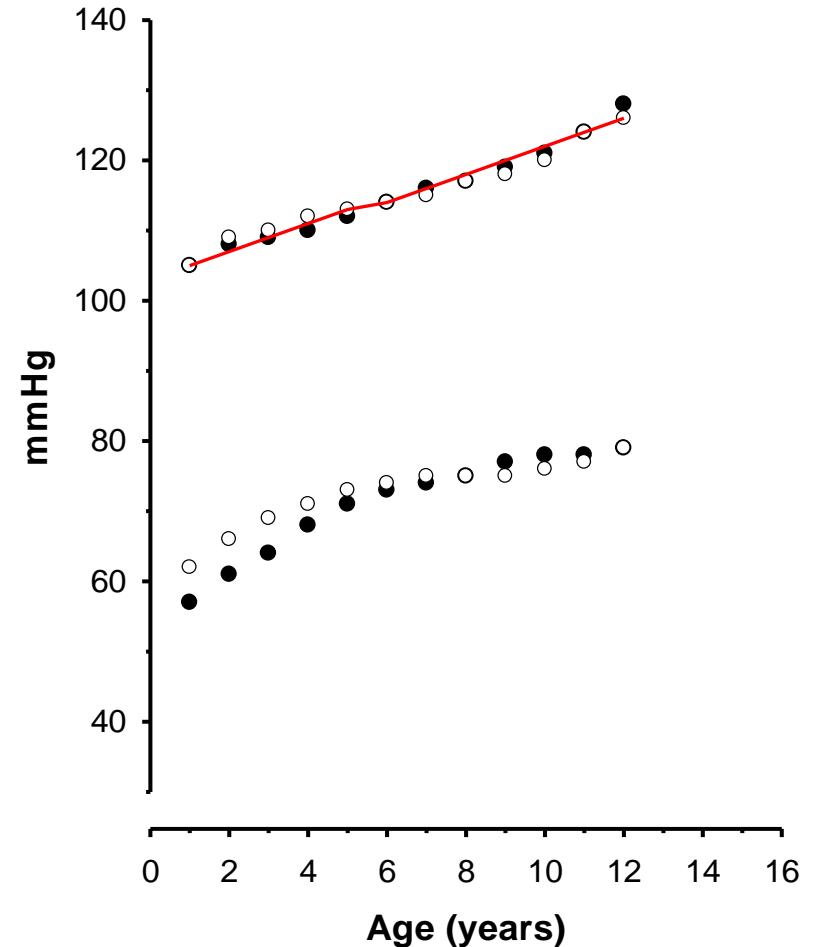
Quick trial to develop formula for 95th percentile in boys and girls at a 95th percentile of height ...

SBP

- 1-5 y: $103 + (\text{age} * 2)$
- 6-12 y: $102 + (\text{age} * 2)$
- ≥ 13 y: 130

DBP

- 1-5 y: $57 + (\text{age} * 3)$
- 6-12 y: $67 + \text{age}$
- ≥ 13 y: 80



Conclusion

- Reference values: statistical methods, not with outcome variables
- Definition of high blood pressure is a complex and cumbersome decision process
- Different user-friendly tool and simplified methods available
- Simplified methods performance is good, some methods better
- Reference values change: new simplified methods needed

Thank you for your attention



Castle Montebello, Bellinzona, Switzerland