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Secular trends in blood pressure in children: a systematic review

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1. RESUME

Tendance séculaire de la pression artérielle chez les enfants : une revue systématique

Introduction

A cause de l'augmentation de l'obésité chez les enfants observée partout dans le monde ces dernières années, on s'attend à ce que les valeurs de pression artérielle (PA) soient également en augmentation. Toutefois, les études décrivant l'évolution de la PA chez les enfants sont peu nombreuses. De plus, les observations sont très différentes d'une étude à l'autre. Nous avons donc réalisé une revue systématique dans le but de déterminer et de mieux comprendre l'évolution de la PA chez les enfants et adolescents ces dernières années.

Méthode

Nous avons effectué une recherche systématique de littérature dans les bases de données MEDLINE, CINHAL, EMBASE, Web of science et Google Scholar. Nous avons complété cette recherche avec une recherche manuelle dans les bibliographies d'articles pertinents. Nous avons inclus les études transversales, reportant les valeurs moyennes de PA ou la prévalence de PA élevée, au minimum à deux périodes distinctes, incluant des enfants et adolescents âgés de 0 à 19 ans, provenant d'une région géographique donnée, et avec un échantillonnage tiré dans la population ou dans des écoles. Deux chercheurs ont extrait les données de manière indépendante à l'aide d'une grille standardisée de recueil de données.

Résultats

Parmi les 1739 publications sélectionnées, nous avons identifié 18 études utilisant des données allant de 1963 à 2012, totalisant 2'042'470 participants. 13 études portaient sur des pays à haut revenu (Etats-Unis, Canada, Irlande, Allemagne, Autriche, Grèce, Russie, Corée du Sud, Japon, Taiwan), 5 études sur des pays à moyen revenu (Turquie, Seychelles, Chine) et aucune étude sur des pays à bas revenu. 13 études tiraient leur échantillon dans des écoles et 5 études dans la population. Le nombre médian de participants par étude était de 8'401 (entre 780 et 1'010'153). La prévalence de surpoids ou d'obésité a augmenté dans 16 études, diminué dans 1 étude et des tendances différentes selon le sexe ont été retrouvées dans 1 étude. La PA a diminué dans 13 études, augmenté dans 4 études et est restée inchangée dans 1 étude.

Conclusion

Alors que pratiquement toutes les études montrent une augmentation du surpoids et de l'obésité, une majorité d'études montrent une baisse des valeurs de PA. Ces résultats nous indiquent que les tendances de PA ne suivent pas celles du surpoids et de l'obésité. Cela suggère que d'autres facteurs atténuent l'effet du surpoids sur la tension artérielle chez les enfants et adolescents.

Secular trends in blood pressure in children: a systematic review

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2. ABSTRACT

Background

Blood pressure (BP) is expected to have increased over time in children in most countries due to the increasing prevalence of childhood obesity worldwide. However, data on secular trends in BP at the population level in children and adolescents are scarce, and trends remain unclear in most countries. We therefore conducted a systematic review of studies assessing secular trends in BP in children and adolescents.

Methods

We conducted a systematic search using MEDLINE, CINHAL, EMBASE databases and Web of science, supplemented by searches in Google Scholar and manual searches of bibliographies of key retrieved articles. We included studies reporting mean levels of BP or the prevalence of elevated BP on at least two different points in time, involving children and adolescents 0 to 19 years old, targeting a defined geographic region, using a cross-sectional design with population- or school-based sampling. Two reviewers independently extracted data using a standardized data collection form.

Results

Out of 1739 citations screened, we identified 18 studies including 2,042,470 participants examined between 1963 and 2012. 13 studies were conducted in high-income countries (USA, Canada, Ireland, Germany, Austria, Greece, Russia, South Korea, Japan, Taiwan), 5 in middle-income countries (Turkey, Seychelles, China) and none in low-income countries. 13 studies were school-based and 5 were population-based. The median number of participants per study was 8,401 (range: 780 to 1,010,153). The prevalence of overweight or obesity increased in 16 studies, decreased in 1 study, and trends differed by sex in 1 study. Blood pressure decreased over time in 13 studies, increased in 4, and did not change in 1.

Conclusion

While almost all studies showed an increase in overweight and obesity, a majority of studies showed a secular decrease in blood pressure in children and adolescents. Our findings suggest that secular trends in blood pressure do not mirror secular trends in overweight. This implies that other factors mitigate the effect of overweight on blood pressure in children and adolescents.

Key words: Children, Adolescents, Hypertension, Secular trends

3. BACKGROUND

Elevated blood pressure (BP) is a major cause of death and morbidity worldwide. It is a leading risk factor for cardiovascular disease in adults [1]. Children with elevated BP have an increased risk of having hypertension as adults [2, 3] and can develop target organ damages such as left ventricular hypertrophy or atherosclerosis early in life [3]. In adults, mean BP has decreased in many high income and middle income countries since a few decades, while an upward trend has been found in several low income countries [4]. This decrease in middle and high income countries may be partly explained by some favorable broad population-based changes in dietary and other factors influencing BP and by to improved detection and treatment of hypertension over time [5].

In children, secular trends in BP are less well described [6-9]. Previous studies have suggested that BP may have decreased in the United States and in several European countries between 1948 and 1998 among children [6, 10]. More recently, different trends were observed in different countries. While BP increased in children in China [11-13] and in Greece [14], it did not increase or decreased in several countries, e.g. Seychelles [15], Japan [16, 17] and Korea [18]. In the USA, some studies documented upward trends in BP [10, 19] while others, surprisingly, did not [20-23]. One study also showed different secular trends in boys and in girls in the USA [24]. The reasons for this heterogeneity are unknown. Therefore, to describe and better understand worldwide secular trends in blood pressure in children and adolescents, we conducted a systematic review of studies assessing such trends.

4. METHODS

We conducted a systematic review following a detailed protocol and analysis plan, consistent with the MOOSE guidelines for meta-analyses and systematic reviews of observational studies [25] and using methods outlined in the Cochrane Handbook for Systematic Reviews of Interventions [26]. The research consisted of the following steps: 1) systematic literature searches, 2) selection of study included, 3) data extraction, and 4) statistical analyses.

Systematic literature searches

We conducted a systematic search of the electronic databases MEDLINE via PubMed (1950 to September 2015), CINHAL (1937 to September 2015), EMBASE (1947 to September 2015), Web of Sciences (1975 to September 2015) for studies assessing trends in blood pressure in children. In addition, we conducted a search in Google Scholar and a hand search of bibliographies in all key retrieved articles. We considered publications in English, French or German, A librarian helped to define search terms and to conduct the electronic literature search.

We used Pubmed search syntax as the basis for all search strategies, using Medical Subject Headings (MeSH) and text terms with Boolean operators. MeSH terms included children-related terms (“children,”, “child,” “adolescent,” “teenagers,” “teens”); blood pressure-related terms (“high, elevated, increase, rising,” “blood pressure,” “BP,” “hypertension”); and trend-related terms (“trends,” “trend study,” “trend studies,” “over time,” “year,” “period”). The studies with the MeSH terms “clinical trials” and “animals” were excluded from the search. The detailed search strategy is available upon request.

Study selection

Two reviewers (CR and AC) independently screened titles, abstracts and full articles from the literature search to determine eligibility **(Figure 1)**. Studies were included if 1) they reported the mean level of BP on at least two different points in time; 2) they were conducted in children and adolescents (0 to 19 years old); 3) they targeted a defined geographic region (i.e., a state, a region, a province, a country) using a (repeated) cross-sectional design and a population- or school-based sampling; and 4) they were written in English, French or German.

Studies were excluded if their samples came from hospitals or specific tertiary referral clinical centers. If some studies used data from the same source (for example from a national survey), these data were used only once. Disagreements about study selection was solved through discussion between the two reviewers.

Data extraction

Two reviewers (CR and AC) independently extracted data from the selected studies using a standardized extraction form. The following characteristics were abstracted from each study: 1) study authors and country and year of publication; 2) study characteristics (study period and design, sampling); 3) characteristics of the participants (number, age, sexe), 4) methods of BP measurement (use of oscillometric vs. auscultatory devices, clinical validation of the device, training or certification of the assessor, use of standardized protocol, cuff size, number of visits and readings at each visits).

We built a quality score for the BP measurement method based on the following items: 1) description of the device used (clinically validated oscillometric or auscultatory); 2) training of the BP assessors; 3) use of a standardized measurement protocol; and 4) use of an appropriate cuff size in relation to arm circumference. If 3 or 4 items were correctly reported, the quality of BP measurement method was considered as high. If 2 or less items were correctly reported, the quality was considered as low.

Statistical analysis

We reported the prevalence of overweight and obesity or the mean body-mass index (BMI) at the initial and the final study period and the change between these two study periods in %/year or kg/m2/year. For BP values, we reported the prevalence of elevated BP or mean BP at the initial and the final study period and the change between these two study periods in %/year or mmHg/year. Data were not pooled as study methods and periods differed largely across studies.

5. RESULTS

Figure 1 shows the selection process of studies included in this review. Some 1739 records were identified, including 482 duplicates. After a first screening of titles and abstracts, 43 potentially relevant full-text articles were reviewed for eligibility. Of these 43 studies, 15 were included. Three additional studies were found by manual searches. Finally, 18 studies were included.

Table 1 shows the main characteristics of the 18 included studies. They were conducted between 1963 and 2012. Some 13 studies were conducted in high-income countries (Austria, Canada, Germany, 2 in Greece, Ireland, Japan, Russia, South-Korea, Taiwan, 3 in the USA) [3, 10, 14, 17, 18, 20, 23, 28, 32-36], 5 in middle-income countries (Turkey, Seychelles, 3 in China) [12, 13, 15, 30] and none in low-income countries [27]. Some 13 studies were school-based [3, 10, 12, 14, 15, 17, 28, 30-35] and 5 were population-based [13, 18, 20, 23, 36]. The total number of participants was 2,042,470 with a median number per study of 8,401 (range: 780 to 1,010,153). The participants were 4 to 19 years old.

Table 2 shows the methods of BP measurement. The auscultatory method was used in 16 studies [3, 10, 12, 13, 17, 18, 20, 23, 28, 30-36] and the oscillometric method in 2 studies [14, 15]. In 10 studies, trained clinical staff measured BP using a standardized protocol [10, 12, 13, 15, 18, 20, 23, 31, 32, 34]. In 11 studies, the cuff size was based on arm circumference [3, 10, 12, 14, 15, 18, 20, 23, 30, 31, 33]. In the remaining 7 studies [13, 17, 28, 32, 34-36], other criteria were used to choose cuff size or only one cuff was available. All BP measurements were taken during a single visit. At this visit, between one and six BP readings were recorded. Most of the studies averaged the different readings to determine BP values. In some studies, one or several items regarding BP measurement methods were not reported. The quality of BP measurement was considered as high in 11 studies (score of 3 or 4) [10, 12, 13, 15, 17, 18, 20, 23, 32, 34] and low in 7 studies (score of 1 or 2) [3, 14, 28, 30, 33, 35, 36]. No study had a quality score of 0.

Table 3 shows the prevalence of overweight and obesity or mean body-mass index (BMI) at the initial and final study period and the change between these two study periods. In 17 studies (94% of all studies) studies, there was an increase in the prevalence of overweight/obesity or in BMI [3, 10, 12-15, 18, 20, 23, 28, 30-36]. In two of these studies, there was an increase in all sex and age categories excepted for one category in which the prevalence of obesity decreased [28, 30]. A decrease in the prevalence overweight/obesity was observed in one study (in Japan) [17]. The change in prevalence of overweight/obesity per year ranged from no change (0.0%/year) [12] and to an increase of +0.7 %/year [15, 30, 35]. The change in mean BMI per year ranged from -0.05 [17] to +0.13 kg/m2/year [20].

Table 4 shows the prevalence of elevated BP or mean BP at the initial and final study period and the change between these two study periods. The 13 studies (72% of all studies) showed a decrease in BP across time [10, 12, 15, 17, 18, 20, 23, 30, 32-36], 4 (22%) an increase [13, 14, 28, 31], 1 (6%) no change [3]. Change in the prevalence of elevated BP per year ranged from -1.2%/year [18] to +2.3%/year [14]. The change in mean systolic BP per year ranged from -1.09 [32] to -0.13 mmHg/year [36]. The change in mean diastolic BP per year ranged from -1.05 [32] to 0.00 mmHg/year [36].

6. DISCUSSION

We conducted a systematic review of studies assessing secular trends in BP in children and adolescents. We identified 18 studies including 2,042,470 participants examined between 1963 and 2012 in 13 different countries. While almost all the studies showed an increase in overweight and obesity, a majority of studies showed a secular decrease in BP in children. Our findings suggest that BP secular trends in pediatric population do not parallel trends in overweight. This implies that other factors mitigate the effect of excess body weight on BP in children and adolescents.

To our knowledge, this is the first systematic review assessing worldwide trends of BP in children and adolescents. We have previously conducted a non-systematic review already suggesting that trend in BP in children were not directly correlated to trends in body weight in children [7]. In adults, in a study having assessed BP trends based on data collected since 1980 in numerous countries worldwide, Daneai et al have shown that the average level of BP has decreased in high and middle income countries, while it has increased in low income countries [4]. Our systematic review indicates that the pattern of BP trends in children was not clearly different according to a country’s economic development. However, no data were available among children in low income countries. In adults, the wide use of anti-hypertensive treatment is likely to have contributed to the decrease in BP, especially in high income countries [5]. Since very few children and adolescents are treated with medication for hypertension, observed secular trends cannot be explained, even partly, by medical treatment. This means that other preventive factors have to be involved in explaining the lack of upward BP trends in children.

Our systematic review has several strengths. First, it is the largest review ever published on BP secular trends in children. Data include more than two million children and adolescents from 13 different countries. Second, we used a systematic review protocol following a high methodology standard (MOOSE, Cochrane) and we screened all major databases. Important limitations should however be noted. First, the quality of BP measurement methods was low in several studies, raising some concerns regarding direct comparison of BP measurements over time. Second, the selected studies are far from covering the whole world. We were able to identify data from 13 countries, and no study was conducted in low-income countries. Another limitation is the fact that we did not have information on other covariates that could influence BP such as diet (e.g., salt intake, fruit and vegetables), physical activity or birth weight. Finally, we could not analyze data at the individual level.

7. PERSPECTIVES

This systematic review updates knowledge on global trends in BP in children and adolescents. Studies are needed to examine trends in BP in children and adolescents in low-income countries. The issue of directionality of secular trends of BP in children, and the relation with trends in the prevalence of overweight, is important to guide public health interventions in pediatric populations. It is fundamental to investigate other determinants of BP like salt-intake or physical activity, as well as more distal (i.e., social) potential determinants and analyze their impact on BP at a population level. In a life course epidemiology perspective, such studies will help guide the primordial prevention of hypertension and cardiovascular diseases [37, 38].

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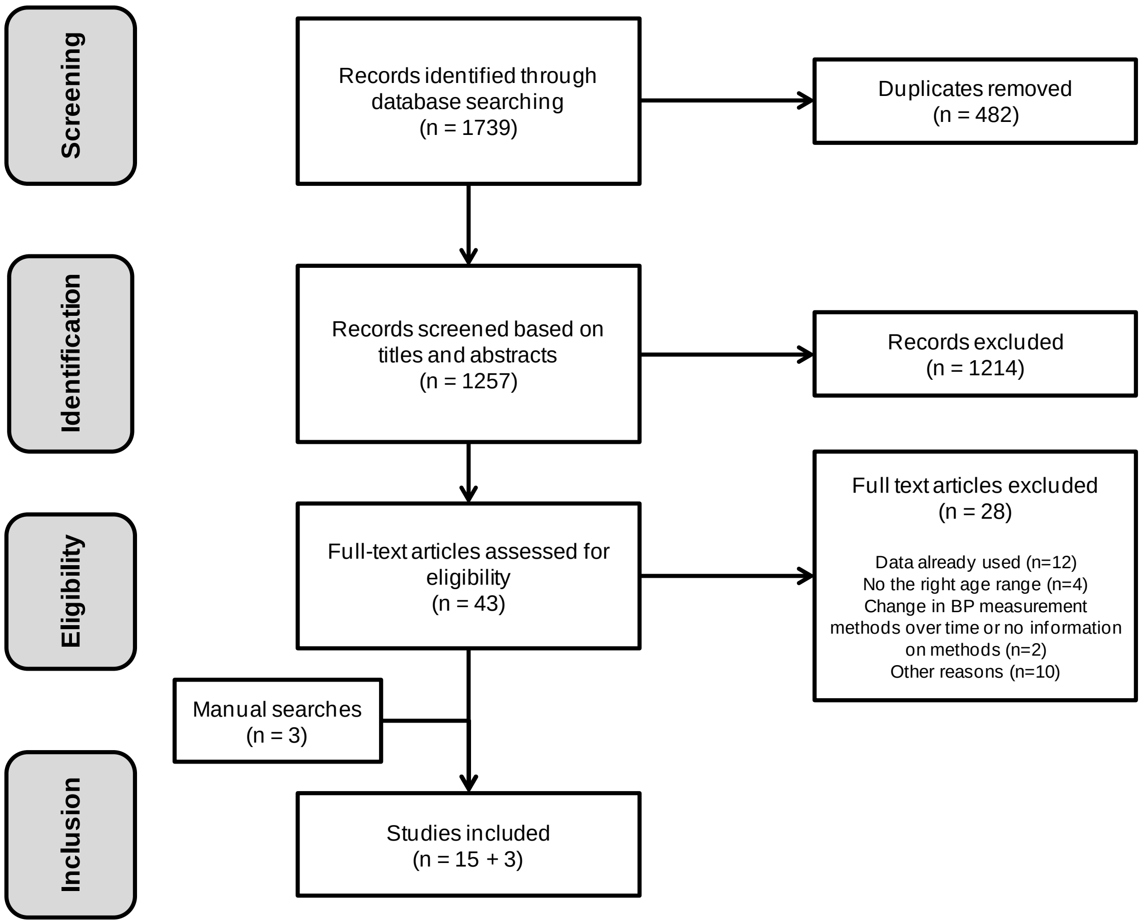
8. FIGURES

Figure 1: Flow diagram of studies assessed and included. BP: blood pressure.



9. TABLES

Table 1: Characteristics of the included studies. M: middle-income countries; H: high-income countries (World Bank classification).

1st author, Journal, Year of publication	Country, Continent	Study period	Sampling	Number of participants	Age
Agirbasli M, J Hum Hypertens, 2008 [30]	Turkey, Europe and Asia	1989-2005	School based, unclear sampling strategy	1 313	15-17y
Chiolero A, Circulation, 2009 [15]	Seychelles, Africa (M)	1998-2006	School based, whole population	25 586	4-18y
Din-Dzietham R, Circulation, 2007 [10]	United States, America (H)	1963-2002	School based, random selection	26 405	8-17y
Dong B, BMJ Open, 2015 [12]	China, Asia (M)	1985-2010	School based, whole population	1 010 153	8-17y
Freedman DS, Pediatrics, 2012 [20]	United States, America (H)	1974-1993	Population based, unclear sampling strategy	11 478	5-17y
Haas GM, Cholesterol, 2012 [33]	Germany, Europe (H)	1994-2003	School based, unclear sampling strategy	2 228	1st grader (around 6y)
Khang YH, Circulation, 2011 [18]	South Korea, Asia (H)	1998-2008	Population based, random selection	5 909	10-19y
Kollias A, J Human Hyper, 2009 [14]	Greece, Europe (H)	2004-2007	School based, unclear sampling strategy	1 004	12-17y
Lin FH, J Hum Hypertens, 2012 [28]	Taiwan, Asia (H)	1996-2006	School based, random selection	2 557	12-14y
McCrindle BW, J Pediatr, 2010 [3]	Niagara, Ontario, Canada (H)	2002-2008	School based, whole population	20 719	14-15y
Rogacheva A, Eur J Public Health, 2007 [34]	Russia, Europe and Asia	1995-2004	School based, whole population	780	15y
Shirasawa T, J Epidemiol, 2012 [17]	Ina, Japan, Asia (H)	1994-2010 (4th grade) and 1997-2010 (7th grade)	School based, whole population	10 894	9-10y and 12-13y

Smpokos EA, Prev Med, 2011 [35]	Greece, Europe (H)	1992-2007	School based, random selection	967	5-8y
Wallner A, Wien Klin Wochenschr, 2010 [36]	Austria, Europe (H)	1986-2005	Population based, whole population	879 660	18y
Watkins D, BMJ, 2004 [32]	Ireland, Europe (H)	1989-2001	School based, random selection	3 007	12 or 15y
Xi B, Int J Cardiol, 2013 [13]	China, Asia (M)	1993-2009	Population based, random selection	2 992	6-17y
Xi B, Am J Hypertens, 2016 [23]	United States, America (H)	1999-2012	Population based, random selection	14 270	8-17y
Zhang YX, Ann Hum Biol, 2012 [31]	China, Asia (M)	2000-2010	School based, random selection	22 548	7-17y

Table 2: Blood pressure measurement methods.

1st author, Journal, Year of publication	Auscultatory or oscillometric method	Training of clinical officer	Standardized protocol	Cuff size	Quality score for BP measurement method	Number of visits (V) and number of readings (R) at each visit	Comments
Agirbasli M, J Hum Hypertens, 2008 [30]	Auscultatory	No information	Yes	Medium sized cuff (arm circumference: 22-32cm)	2	V: 1; R: 3	BP: average of 2 readings
Chiolero A, Circulation, 2009 [15]	Oscillometric (Omron M5; clinically validated)	Yes	Yes	Based on arm circumference	4	V: 1; R : 2	Children could be examined more than once (1 visit every 3 or 4 years); BP: average of 2 readings at 1 minute interval
Din-Dzietham R, Circulation, 2007 [10]	Auscultatory	Yes	Yes	Cuff of appropriate size based on arm circumference only since NHANES 3 (1988-94)	4	V: 1; R: 3-6	BP measurements methods varied over time and between surveys; BP: average of all readings; SBP: K1; DBP: K4 or K5
Dong B, BMJ Open, 2015 [12]	Auscultatory	Yes	Yes	Cuff of appropriate size based on arm circumference	4	V: 1; R: 3	BP: average of 3 readings; SBP: K1; DBP: K5
Freedman DS, Pediatrics, 2012 [20]	Auscultatory	Yes	Yes	Cuff of appropriate size based on arm circumference	4	V: 1; R: 6 (2*3 R by 2 trained observers)	BP: average of the 6 readings; DBP: K4

Haas GM, Cholesterol, 2012 [33]	Not reported	Yes	No information	Cuff of appropriate size based on arm circumference	2	V: 1; R: not reported	
Khang YH, Circulation, 2011 [18]	Auscultatory	Yes	Yes	Based on arm circumference	4	V: 1; R: 2-3	BP: average of the 2 first readings; SBP: K1;DBP: K5
Kollias A, J Human Hyper, 2009 [14]	Oscillometric (Welch Allyn Vital Sign Monitor)	No information	No information	Cuff of appropriate size based on arm circumference	2	V: 1; R:3	BP: average of 3 readings
Lin FH, J Hum Hypertens, 2012 [28]	Auscultatory	No information	No information	Cuff of appropriate size	2	V: 1; R: 2	BP: average of 2 readings; SBP: K1; DBP: K5
McCrindle BW, J Pediatr, 2010 [3]	Not reported	No information	Yes	Cuff of appropriate size based on arm circumference	2	V: 1; R: 1-3	BP: 1st reading; if BP≥ 135/85, BP was measured twice and the mean of the 3 readings was recorded
Rogacheva A, Eur J Public Health, 2007 [34]	Auscultatory	Yes	Yes	One cuff (12cm x 35 cm)	3	V: 1; R: 2	BP: average of 2 readings; SBP: K1; DBP: K5
Shirasawa T, J Epidemiol, 2012 [17]	Auscultatory	Yes	No information	Cuff of 2 sizes (9cm and 12cm)	3	V: 1; R:1-3	BP: 1st reading; if SBP/DBP >120/70 mmHg, BP was measured 3 times and 3rd reading used
Smpokos EA, Prev Med, 2011 [35]	Auscultatory	No information	No information	No information	1	V: 1; R: 3	BP: average of 2 readings
Wallner A, Wien Klin Wochenschr, 2010 [36]	Auscultatory	No information	No information	No information	1	V: 1; R:No information	-

Watkins D, BMJ, 2004 [32]	Auscultatory	Yes	Yes	Same standard adult cuff used in each survey	3	V: 1; R: 2 (Survey of 1990) or 1 (Survey of 2000)	Survey of 1990: average of 2 readings
Xi B, Int J Cardiol, 2013 [13]	Auscultatory	Yes	Yes	No information	3	V: 1; R: 3	BP: average of the last 2 readings
Xi B, Am J Hypertens, 2016 [23]	Auscultatory	Yes	Yes	Based on arm circumference	4	V. 1; R: 1-3 (84.6% had 3 R)	BP: average of the last 2 readings; DBP: K1; DBP: K4 or K5
Zhang YX, Ann Hum Biol, 2012 [31]	Auscultatory	Yes	Yes	Cuff of appropriate size based on arm circumference	4	V: 1; R: 2	BP: average of the 2 readings; DBP: K5

Table 3: Trends in mean body mass index (BMI) or in the prevalence of overweight/obesity. Sem: standard error of the mean; SD: standard deviation; CI: confidence interval; NR: not reported.

1st author, journal, year of publication	Body weight category or mean BMI	B: boys; G: girls	Initial study period	Final study period	Change in prevalence of overweight/obesity (/year) or in mean BMI (kg/m2/year)
Agirbasli M, J Hum Hypertens, 2008 [30]	Overweight		*1989-1990*	*2004-2005*	
	[%]	B, aged 15	1.4	15.7	**+0.9%**
		B, aged 16	2.2	22.5	**+1.3%**
		B, aged 17	9.2	21	**+0.7%**
		G, aged 15	3.4	19	**+1.0%**
		G, aged 16	7.0	6.0	**-0.1%**
		G, aged 17	2.7	4.1	**+0.1%**
Chiolero A, Circulation, 2009 [15]	Overweight		*1998-2000*	*2004-2006*	
	[% (sem)]	B	10.7 (0.4)	16.0 (0.4)	**+0.7%**
		G	15.1 (0.5)	19.5 (0.4)	**+0.6%**
		B & G	12.9 (0.3)	17.7 (0.3)	**+0.6%**
Din-Dzietham R, Circulation, 2007 [10]	Obesity		*1963-70*	*1999-2002*	
	[% (sem)]	B & G; non-hispanic Blacks	5.4 (1.0)	22.4 (1.2)	**+0.4%**
		B & G; non-hispanic Whites	5.6 (0.4)	14.1 (1.7)	**+0.2%**
Dong B, BMJ Open, 2015 [12]	Obesity		*1985*	*2010*	
	[%]	B	0.0	3.4	**+0.1%**
		G	0.0	0.9	**0.0%**
Freedman DS, Pediatrics, 2012 [20]	BMI		*1974*	*1993*	
	[kg/m2 (SD)]	B	17.5 (3)	20.0 (5)	***+0.13***
		G	17.8 (4)	20.2 (5)	***+0.13***

Haas GM, Cholesterol, 2012 [33]	BMI		*1994*	*2003*	
	[kg/m2 (SD)]	B	15.8 (2.4)	15.9 (2.4)	***+0.01***
		G	15.6 (2.4)	15.9 (1.9)	***+0.03***
Khang YH, Circulation, 2011 [18]	BMI		*1998*	*2007/8*	
	[kg/m2 (sem)]	B & G	19.9 (0.1)	21.0 (0.1)	***+0.11***
Kollias A, J Human Hyper, 2009 [14]	Obesity		*2004*	*2007*	
	[%]	B & G	9.2	10.9	**+0.6%**
Lin FH, J Hum Hypertens, 2012 [28]	BMI		*1996*	*2006*	
	[kg/m2 (sem)]	B	21.1 (0.1)	21.6 (0.2)	***+0.05***
		G	20.7 (0.1)	20.5 (0.2)	***-0.02***
McCrindle BW, J Pediatr, 2010 [3]	Obesity		*2002-2003*	*2007-2008*	
	[%]	B & G	12	13	**+0.2%**
Rogacheva A, Eur J Public Health, 2007 [34]	BMI		*1995*	*2004*	
	[kg/m2 (SD)]	B	19.6 (2.2)	19.7 (2.1)	***+0.01***
		G	19.7 (2.6)	20.1 (2.6)	***+0.04***
Shirasawa T, J Epidemiol, 2012 [17]	Change in mean BMI per year		*1994*	*2010*	
	[kg/m2/year (95% CI)]	B, 4th grade	NR	NR	***-0.04***
		G, 4th grade	NR	NR	***-0.03***
			1997	*2010*	
		B, 7th grade	NR	NR	***-0.05***
		G, 7th grade	NR	NR	***-0.04***
Smpokos EA, Prev Med, 2011 [35]	Overweight		*1992-1993*	*2006-2007*	
		B	19.4	33.7	**+1.0%**
		G	24.5	34.6	**+0.7%**

Wallner A, Wien Klin Wochenschr, 2010 [36]	Obesity		*1986-1990*	*2001-2005*	
	[%]	B	2.6	5.4	**+0.1%**
Watkins D, BMJ, 2004 [32]	BMI		*1990*	*2000*	
	[kg/m2 (SD)]	B, aged 12	18.9 (3.3)	19.4 (3.4)	***+0.05***
		G, aged 12	19.2 (2.9)	20.3 (3.6)	***+0.11***
		B, aged 15	20.4 (2.5)	20.6 (3.3)	***+0.02***
		G, aged 15	21.9 (3.1)	22.0 (3.4)	***+0.01***
Xi B, Int J Cardiol, 2013 [13]	Obesity		*1993*	*2009*	
	[% (sem)]	B & G	6.1 (0.6)	13.1 (1.1)	**+0.4%**
Xi B, Am J Hypertens, 2016 [23]	Obesity		*1999-2002*	*2009-2012*	
	[% (sem)]	B & G	17.1 (1.0)	20.3 (0.7)	**+0.2%**
Zhang YX, Ann Hum Biol, 2012 [31]	Overweight		2000	2010	
	[% (95% CI)]	B	12.8 (11.7-13.8)	17.5 (16.2-18.7)	**+0.5%**
		G	7.7 (6.9-8.6)	11.8 (10.8-12.9)	**+0.4%**
		B & G	10.3 (9.6-10.9)	14.7 (13.8-15.5)	**+0.4%**

Table 4: Trends in mean blood pressure or in the prevalence of elevated blood pressure (EBP). Sem: standard error of the mean; SD: standard deviation; CI: confidence interval; SBP: systolic blood pressure; DBP: diastolic blood pressure; NR: not reported.

1st author, journal, year of publication	EBP Definition	B: boys; G: girls	Initial study period	Final study period	Change in prevalence of elevated BP (/year) or in mean BP (mmHg/year)
Agirbasli M, J Hum Hypertens, 2008 [30]	Change in mean BP per year		*1989-1990*	*2004-2005*	
	[mmHg/year (95% CI)]	B	NR	NR	**-0.45/-0.36**
		G	NR	NR	**-0.35/ -0.39**
Chiolero A, Circulation, 2009 [15]	SBP/DBP ≥95th percentile (CDC Definition)		*1998-2000*	*2004-2006*	
	[% (sem)]	B	8.4 (0.4)	6.9 (0.3)	**-0.2%**
		G	9.8 (0.4)	7.8 (0.3)	**-0.3%**
		B & G	9.1 (0.3)	7.4 (0.2)	**-0.2%**
Din-Dzietham R, Circulation, 2007 [10]	EBP: SBP/DBP ≥95th percentile (CDC definition)		*1963-70*	*1999-2002*	
	[% (sem)]	B & G	37.2 (0.7)	3.7 (0.4)	**-0.9%**
Dong B, BMJ Open, 2015 [12]	ESBP: systolic BP ≥ 95th percentile		*1985*	*2010*	
	[% (sem)]	B	5.1 (0.1)	4.9 (0.1)	**0.0%**
		G	5.5 (0.1)	3.5 (0.1)	**-0.1%**
Freedman DS, Pediatrics, 2012 [20]	EBP: SBP/DBP ≥90th percentile		*1974*	*1993*	
	[%]	B	5.8	4.1	**-0.1%**
		G	8.1	5.8	**-0.1%**
Haas GM, Cholesterol, 2012 [33]	SBP/DBP		*1994*	*2003*	
	[mean (SD)]	B	105.1 (10.0)/70.7 (8.4)	101.1 (7.7)/63.5 (5.7)	***-0.44/-0.80***
		G	105.2 (10.0)/71.0 (8.5)	100.9 (7.6)/64.1 (7.0)	***-0.47/-0.76***

Khang YH, Circulation, 2011 [18]	EBP: SBP/DBP ≥95th percentile (CDC definition)		*1998*	*2007/8*	
	[% (95% CI)]	B	12.5 (10.2-14.8)	4.4 (3.0-5.7)	**-0.8%**
		G	13.6 (11.1-16.0)	1.9 (0.9-2.8)	**-1.2%**
Kollias A, J Human Hyper, 2009 [14]	EBP: SBP/DBP ≥95th percentile (CDC definition)		*2004*	*2007*	
	[%]	B & G	16.1	22.9	**2.3%**
Lin FH, J Hum Hypertens, 2012 [28]	EBP: SBP/DBP ≥ 95th percentile (internal reference)		*1996*	*2006*	
	[%]	B	22.8	29.7	**0.7%**
		G	12.5	20.7	**0.8%**
McCrindle BW, J Pediatr, 2010 [3]	EBP: SBP/DBP ≥95th percentile		*2002-2003*	*2007-2008*	
	[%]	B & G	9	9	**0.0%**
Rogacheva A, Eur J Public Health, 2007 [34]	SBP/DBP		*1995*	*2004*	
	[mean (SD)]	B	119 (12)/62 (10)	116 (11)/59 (8)	***-0.33/-0.33***
		G	115 (11)/64 (8)	113 (9)/59 (8)	***-0.22/-0.55***
Shirasawa T, J Epidemiol, 2012 [17]	Change in mean BP per year		*1994*	*2010*	
	[mmHg/year (95% CI)]	B, 4th grade	NR	NR	***-0.35/-0.45***
		G, 4th grade	NR	NR	***-0.43/-0.43***
			1997	*2010*	
		B, 7th grade	NR	NR	***-0.51/-0.42***
		G, 7th grade	NR	NR	***-0.47/-0.36***

Smpokos EA, Prev Med, 2011 [35]	SBP/DBP		*1992-1993*	*2006-2007*	
	[mean (SD)]	B	104.3 (0.6)/60.4 (0.5)	91.3 (0.8)/57.0 (0.6)	***-0.86/-0.22***
		G	102.0 (0.7)/59.8 (0.5)	88.9 (0.7)/55.3 (0.6)	***-0.86/-0.30***
Wallner A, Wien Klin Wochenschr, 2010 [36]	SBP/DBP [mean (SD)]		*1986-1990*	*2001-2005*	
		B	128.2/71.5	126.30/71.5	***-0.13/0.00***
Watkins D, BMJ, 2004 [32]	SBP/DBP		*1990*	*2000*	
	[mean (SD)]	B, aged 12	111.0 (11.6)/67.9 (9.5)	102.9 (11.6)/59.1 (8.7)	***-0.81/-0.88***
		G, aged 12	111.5 (12.2)/70.9 (9.1)	104.2 (12.1)/60.4 (8.6)	***-0.73/-1.05***
		B, aged 15	123.3 (12.4)/73.4 (9.4)	113.2 (12.8)/62.5 (8.4)	***-1.09/-0.98***
		G, aged 15	118.3 (11.8)/74.3 (8.8)	109.9 (11.1)/64.5 (8.7)	***-0.84/-0.98***
Xi B, Int J Cardiol, 2013 [13]	EBP: SBP or DBP ≥ 95th percentile (Chinese reference percentile)		*1993*	*2009*	
	[% (sem)]	B	8.2 (0.8)	12.6 (1.5)	**0.3%**
		G	7.0 (0.8)	15.2 (1.8)	**0.5%**
Xi B, Am J Hypertens, 2016 [23]	EBP: SBP/DBP ≥95th percentile (CDC definition)		*1999-2002*	*2009-2012*	
	[% (sem)]	B	3.2 (0.4)	1.8 (0.5)	**-0.1%**
		G	2.6 (0.5)	1.4 (0.2)	**-0.1%**
		B & G	2.9 (0.3)	1.6 (0.3)	**-0.1%**
Zhang YX, Ann Hum Biol, 2012 [31]	EBP: SBP/DBP ≥95th percentile (CDC definition)		2000	2010	
	[% (95% CI)]	B	19.3 (18.1-20.5)	26.1 (24.7-27.6)	**0.7%**
		G	14.7 (13.6-15.8)	19.8 (18.4-21.1)	**0.5%**