Papers

Trends in blood pressure over 10 years in adolescents: analyses of cross sectional surveys in the Northern Ireland Young Hearts project

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Abstract

Objective To examine secular trends in blood pressure over a 10 year period between two representative cohorts of adolescents from Northern Ireland.

Design Repeat cross sectional study.

Setting Randomly selected post-primary schools from Northern Ireland.

Participants 1015 adolescents studied between 1989 and 1990, and 2017 adolescents studied between 1999 and 2001. Participants were aged 12 or 15 years.

Main outcome measures Systolic and diastolic blood pressure measured by one observer in each study.

Results The four groups for sex and age showed decreases in both systolic blood pressure (mean decrease 7.7 mm Hg to 10.0 mm Hg) and diastolic blood pressure (8.8 mm Hg to 11.0 mm Hg). These decreases were not accounted for by adjustment for potential confounders including age, height, body mass index, smoking, physical activity, aerobic fitness, and stratification of school by education board area and type. The findings were not altered by additional adjustment for social class, pubertal status, birth weight, and infant feeding. No evidence was found of systematic variation between observers.

Conclusions Substantial decreases in systolic and diastolic blood pressure over the past decade in adolescents from Northern Ireland are likely to have important benefits to public health and may help offset the increasing risk of cardiovascular disease due to increases in obesity.

Introduction

Raised blood pressure is a major risk factor for cardiovascular disease.[1] It tracks relatively well from youth to adulthood, making blood pressure in youth a useful predictor of essential hypertension in adulthood.[2 3] Patterns of risk factors in populations, such as raised blood pressure, are not static over time, and predate subsequent changes in patterns of cardiovascular disease.[4] Evidence from the United States and worldwide shows that the mean blood pressure of adults has decreased over the past two decades.[5 6] Fewer data are available on trends in youth; findings from the United States have been inconsistent, whereas in the United Kingdom, secular decreases in blood pressure have been noted in successive cohorts of university students.[7–9]

Trends in blood pressure in adolescents are a marker of the future population burden of cardiovascular disease and may be of particular relevance in areas with high disease rates.[10] We examined trends in blood pressure in representative samples of adolescents in Northern Ireland, a region with a consistently high prevalence of cardiovascular disease.[11]

Participants and methods

The first Young Hearts study (YH1990) was carried out in 1989-90 to evaluate the status of major modifiable coronary risk factors, including blood pressure, within the adolescent population of Northern Ireland. Random samples of males and females aged 12 and 15 years participated, with around 250 participants in each of the four groups for age and sex. Details of the study design are presented elsewhere.[12] A further cross sectional survey—Young Hearts 2000 (YH2000)—was carried out in 1999-2001. Around 500 adolescents in each of the four groups were recruited through post-primary schools. The sampling procedure of both surveys sought to take account of the structure of secondary education within Northern Ireland, both by selection policy (grammar and non-grammar) and geographical spread. Schools were stratified by education board area and by type of school. A two stage cluster sample of adolescents was obtained from each stratum. The primary sampling units were schools, randomly selected with probabilities proportional to school size: 16 schools took part in the first study and 36 in the second (two schools participated in both). The secondary units for study were the adolescents themselves, randomly selected from the four groups. The number of adolescents in each group was proportional to the corresponding population number. Screening took place at schools during normal school hours.

Blood pressure measurement

In each study, blood pressure readings were carried out by one observer. The observers were both paediatricians, received additional training from prerecorded tapes, and became familiar to the participants as the study protocol was carried out.

The procedure was explained to participants in advance. Tight clothing was removed from the arm, and blood pressure was measured with participants sitting after at least five minutes' rest. Measurements were taken with the UK random-zero Hawksley sphygmomanometer.[13] Instruments were calibrated by the same laboratory before both studies: two instruments were used in the first study and three in the second. They were checked for accuracy at intervals by comparison with a standardised sphygmomanometer. The same standard cuff size was used in both surveys. This adult cuff covered at least two thirds of the upper arm's length, and the bladder encircled the arm's circum-

Table 1 Mean (SD) systolic and diastolic blood pressures in participants from Young Hearts studies, 1990 and 2000

Age; blood pressure reading (mm Hg)	Males			Females		
	1990	2000	P value	1990	2000	P value
12 years:	n=247	n=530		n=248	n=514	
Systolic	111.0 (11.6)	102.9 (11.6)	<0.001	111.5 (12.2)	104.2 (12.1)	<0.001
Diastolic	67.9 (9.5)	59.1 (8.7)	<0.001	70.9 (9.1)	60.4 (8.6)	<0.001
15 years:	n=249	n=485		n=252	n=482	
Systolic	123.3 (12.4)	113.2 (12.8)	<0.001	118.3 (11.8)	109.9 (11.1)	<0.001
Diastolic	73.4 (9.4)	62.5 (8.4)	<0.001	74.3 (8.8)	64.5 (8.7)	<0.001

ference. The cuff was deflated by around 2 mm Hg each second and was completely deflated between readings. Systolic blood pressure was expressed as the Korotkoff phase I value. In adults, Korotkoff V (disappearance of pulse sounds) is used for the diastolic phase, whereas in young people pressure applied at the antecubital fossa may eliminate the fifth phase so that sounds persist down to 0 mm Hg.[14] We therefore used the Korotkoff IV value (muffling of pulse sounds) for participants aged 12 and the Korotkoff V value for participants aged 15. The first study used the means of two separate readings taken close together, but time constraints in the second study allowed only one reading on each participant. All readings were taken to the nearest 2 mm Hg.

Height was measured to the nearest millimetre and weight to the nearest 100 g. In the first study pubertal status was assessed by a modified Tanner score,[15] whereas in the second study it was assessed by a paediatrician (DCW) on the basis of non-genital secondary hair growth, vocal timbre, body habitus, and muscular development, and breast development in females. Cardiorespiratory fitness was estimated in both studies by indirect calculation of oxygen consumption at maximal dynamic effort (VO_2max) in a 20 m shuttle run.[16] Smoking status was assessed as part of a confidential self-report questionnaire completed by each participant; regular smoking was defined as consumption of one or more cigarettes a week. Birth weight of participants was recalled by parents as part of a confidential parental questionnaire. Social class was based on the current occupation of the head of the household and classified according to the 1990 standard occupational classification of the Office of Population, Censuses, and Surveys.

To check for any variation between observers in blood pressure measurements, the observers took readings from 50 randomly selected adolescents within the study age range from a non-participating Belfast school. The first observer used one sphygmomanometer for 25 measurements and another for the remaining 25 measurements. The order of instruments was reversed for the second observer.

Statistical analysis

We performed separate analyses for each of the four groups. Continuous variables and categorical variables in both studies were compared by t tests and χ^2 tests, respectively. Multivariate regression analysis was used to estimate the changes in mean systolic and diastolic blood pressures between the two studies. As unadjusted findings for the complete cohorts were similar to those for adolescents without missing data on confounders, we only present the data for participants with complete data. All data were analysed with SPSS for Windows version 11.0.

Results

The response rate for the second study was lower than that for the first (65.3% compared with 79.3%). Reasons for non-participation were similarly distributed between both studies:

40% of respondents objected to a blood test, 26% were not interested in taking part, 16% were unwilling to miss schoolwork, and 4% were unwilling to undergo a fitness test. On the basis of limited self-reported anthropometric data from non-participants, body mass index (weight (kg)/(height (m)^2)) was 0.9 lower in non-participants than in participants.

Although there was disagreement between the observers for some blood pressure readings, as evidenced by the large standard deviations of the differences between the two observers (mean (SD) difference: systolic 0.10 (10.40) mm Hg; diastolic 0.24 (10.76) mm Hg), there was no evidence of systematic variation between them, with similar mean systolic and diastolic blood pressures being recorded by both. In regression models with systolic and diastolic blood pressure as the dependent variables, and the effects of participant, machine, and observer as explanatory variables, there was no evidence that observer effect had influenced blood pressure measurement (data not shown).

The analyses in tables 2 and 3 are based on participants with complete data, representing 99% of the original cohorts. We found consistent differences in mean blood pressure between both sexes, males tending to have higher systolic and lower diastolic blood pressure than age matched females (table 1). These findings remained largely unchanged between the two studies. Correlations between systolic and diastolic blood pressure were of a similar order (0.5 to 0.65) in both studies and for all four groups.

Table 2 shows the summary statistics for potential confounding or mediating variables. Mean height increased substantially in the four groups (by 1.9 cm to 3.0 cm, P < 0.001 for each group) as did mean weight (by 1.5 kg to 4.2 kg, P < 0.001 to P = 0.04), with the largest increases among 12 year olds. Mean body mass index only increased significantly in 12 year old females. Mean birth weight changed little between the first and second study (3372 g versus 3408 g, respectively; P = 0.10). The proportion of females of both ages who smoked regularly, increased. Mean maximal aerobic fitness and mean habitual physical activity showed more favourable trends in males. The proportion of participants who were breast fed as infants increased in all four groups over the 10 year period, as did the proportion from a non-manual background (59.2% versus 72.8%; P < 0.001).

Table 3 shows the change in mean systolic and diastolic blood pressure for the four groups between the first and second study, unadjusted and adjusted for age, height, body mass index, smoking status, physical activity, and stratification of school. Substantial decreases were found consistently across all four groups for both systolic blood pressure (mean unadjusted decrease 7.7 mm Hg to 10.0 mm Hg) and diastolic blood pressure (8.8 mm Hg to 11.0 mm Hg); this represents an annual decline of 0.73 mm Hg to 1.01 mm Hg and 0.89 mm Hg to 1.09 mm Hg, respectively. Additional modelling, controlling for age, height, body mass index, smoking status, physical activity, stratification of school, breast feeding, and fitness, and then additionally control-

Table 2 Characteristics of participants of Young Hearts studies, 1990 and 2000. Values are means (standard deviations) unless stated otherwise

	Participants aged 12						Participants aged 15					
	Males			Females			Males			Females		
Characteristics	1990	2000	P value	1990	2000	P value	1990	2000	P value	1990	2000	P value
Sample size	251	530		248	514		249	485		252	482	
Age (years)	12.51 (0.28)	12.53 (0.28)	0.46	12.49 (0.34)	12.50 (0.27)	0.56	15.47 (0.30)	15.48 (0.28)	0.61	15.51 (0.29)	15.48 (0.29)	0.15
Height (cm)	149.8 (7.9)	152.3 (7.7)	<0.001	150.8 (7.5)	153.7 (7.1)	<0.001	169.0 (7.1)	172.0 (7.9)	<0.001	160.6 (5.9)	162.5 (5.8)	<0.001
Weight (kg)	42.6 (9.4)	45.3 (10.4)	<0.001	44.0 (9.0)	48.2 (10.7)	<0.001	58.6 (9.4)	61.1 (11.7)	0.002	56.6 (8.5)	58.1 (10.1)	0.03
Body mass index (kg/m^2)	18.9 (3.3)	19.4 (3.4)	0.06	19.2 (2.9)	20.3 (3.6)	<0.001	20.4 (2.5)	20.6 (3.3)	0.44	21.9 (3.1)	22.0 (3.4)	0.85
No (%) of self-reported smokers	8 (3)	32 (6)	0.14	4 (2)	25 (5)	0.046	52 (21)	101 (21)	1.00	41 (16)	127 (26)	0.003
Predicted VO$_2$max (ml/kg/min)*	45.3 (5.3)	46.5 (6.4)	0.006	40.0 (5.3)	39.8 (6.9)	0.68	51.1 (6.0)	53.6 (6.9)	<0.001	40.4 (5.4)	41.3 (6.9)	0.08
Physical activity†	33.5 (14.3)	31.5 (15.6)	0.085	24.5 (13.2)	22.0 (13.6)	0.015	27.2 (15.8)	26.7 (14.5)	0.73	17.2 (12.0)	18.1 (12.9)	0.32
Reported birth weight (g)	3384 (601)	3479 (560)	0.042	3307 (512)	3358 (511)	0.21	3438 (558)	3433 (597)	0.92	3357 (513)	3358 (524)	0.98
No (%) of sexual maturity‡	226 (90)	488 (92)	0.39	139 (56)	319 (62)	0.13	22 (9)	0	<0.001	0	0	0.55
No (%) breast fed	50 (20)	159 (30)	0.003	57 (23)	159 (31)	0.029	37 (15)	150 (31)	<0.001	33 (13)	174 (36)	<0.001
No (%) of non-manual social class	146 (58)	381 (72)	<0.001	156 (63)	370 (72)	0.026	147 (59)	369 (76)	<0.001	139 (55)	347 (72)	<0.001

*Oxygen consumption at maximal dynamic effort in 20 m shuttle run.
†Scores up to 100.
‡Tanner I-III.

ling for birth weight, social class, and pubertal status, had negligible effects on the results presented in table 3 (data not shown).

Discussion

Large decreases in blood pressure have occurred among adolescents aged 12 and 15 years from Northern Ireland over the decade from 1990. The magnitude of the trends is greater than previously reported, and could not be accounted for by several important mediating or confounding factors.

Strengths and limitations

Our study was population based, and participants were selected randomly. The response rate was lower for the second of the two studies (YH2000), and although there was some evidence (on the basis of self-report) that non-participants were thinner than participants, this bias would have tended to moderate the declines in blood pressure. We attempted to check for variations between observers and instruments and to minimise the possible influence of any variations. Although our observer validation exercise was of small scale and limited, particularly for reproducing blood pressure measurement technique after the 10 years from the first study, it showed no substantial effect from variation between observers. Birth weight was based on parental recall, which has been shown to give a reliable estimation of recorded birth weight in participants in YH1990.[17] The Tanner scale and the visual assessment of pubertal status are both likely to be poor and arbitrary measures of the range of sexual maturity, but adjustment for pubertal status did not alter the findings and, moreover, we do not think that age at puberty will have shifted to anything except a negligible degree over the 10 years between the studies. While some caution is indicated in assessing the declines, the lack of systematic variation between observers, the use of random-zero calibrated sphygmomanometers, coupled with the consistency with published literature, indicate that the findings are unlikely to be artefactual and that bias is unlikely to explain more than a modest proportion of the declines in blood pressure noted.

Comparison with other studies

Several studies in developed countries have examined secular trends in blood pressure among children. In the United States, data from both the National Health (and Nutrition) Examination surveys and the Bogalusa heart study showed variable decreases in blood pressure in most groups of 6-17 year olds from the 1960s to the early 1990s.[7 18] In England, mean systolic blood pressure in 5-15 year olds declined by 1.4 mm Hg to 1.7 mm Hg between 1995 and 1998, with a small decrease in diastolic blood pressure over the same period.[19] A larger number of studies have shown that decreases in blood pressure have been occurring in

Table 3 Decreases in mean blood pressure over 10 years in participants of Young Hearts studies, 1990 and 2000. Values are means (95% confidence intervals)

	Systolic blood pressure (mm Hg)		Diastolic blood pressure (mm Hg)	
Age and sex	Unadjusted decrease	*Adjusted decrease	Unadjusted decrease	*Adjusted decrease
12 years:				
Males	8.1 (6.4 to 9.9)	9.5 (8.0 to 11.1)	8.8 (7.4 to 10.2)	9.7 (8.4 to 11.0)
Females	7.7 (5.9 to 9.5)	10.4 (8.7 to 12.0)	10.5 (9.1 to 11.8)	11.9 (10.6 to 13.1)
15 years:				
Males	10.0 (8.1 to 12.0)	11.6 (9.8 to 13.3)	11.0 (9.6 to 12.4)	11.6 (10.3 to 12.9)
Females	8.4 (6.7 to 10.2)	8.7 (7.0 to 10.3)	9.8 (8.5 to 11.1)	10.2 (8.9 to 11.5)

P<0.001 for all groups (unadjusted and adjusted).
*Adjusted for body mass index, age, height, physical activity score, self-reported smoking, and stratification.

young adults in Europe and the United States over the 50 years from 1948.[20]

Explanation of findings

Factors responsible for these secular decreases in blood pressure have not yet been established. The downward trend seems to be occurring despite positive associations between blood pressure in children and height and indices of fatness, both of which increased between the two Young Hearts studies (and may account for the greater adjusted mean decreases compared with the unadjusted decreases).[21 22] Similar findings have been observed in the Health Survey for England, when increases in body mass index were accompanied by decreases in blood pressure.[19]

Birth weight, as the most accessible marker of intrauterine growth, has shown a consistent inverse association with subsequent blood pressure, and it has been proposed that raised blood pressure may be a response to fetal undernutrition, causing long term changes in arterial structure in the child.[23] An estimated increase in birth weight of around 1000 g would be required to produce a 2 mm Hg decrease in systolic blood pressure in people aged 50,[23] and even this effect size has recently been questioned, with the suggestion that the inverse association may reflect the impact of selective emphasis of particular results and inappropriate adjustment for confounders.[24] The relatively small secular changes in mean birth weight (from −11 g to 94 g for the different groups) between our two cohorts would not by themselves explain the magnitude of decreases in blood pressure.

Alterations in salt intake may be important. A recent systematic review of trials of salt restriction reported only small reductions in blood pressure.[25] In adolescents randomised in infancy to a low or a normal sodium diet, however, systolic and diastolic blood pressure were lower after 15 years in those in the intervention arm, suggesting that sodium restriction in infancy may have greater effects on later blood pressure than salt reductions in adulthood,[26] and although these findings should be interpreted with caution, as they are based on incomplete follow up, they are, nevertheless, provocative.

Implications for public health

Our observations suggest that several of the major determinants of adult blood pressure are set in train in early life. Mild increases of blood pressure in early life are known to increase long term cardiovascular risk.[10] It is therefore encouraging that blood pressure levels seem to have fallen over time in this population, and there are likely to be considerable public health benefits in such a population decrease if it is sustained into adult life. It may also be that benefits from decreasing blood pressure offset increasing cardiovascular risk from population increases in obesity.

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What is already known on this topic

Trends in blood pressure in early life are a marker of subsequent cardiovascular risk

Studies have shown secular decreases in blood pressure in adults, but evidence is less consistent for younger populations

What this study adds

Decreases in blood pressure, not explained by change in body composition or birth weight, have occurred in adolescents in Northern Ireland over the past decade

The major determinants of adult blood pressure seem to be set in early life

Potentially modifiable determinants need to be ascertained

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