A Longitudinal Evaluation of Blood Pressure in Children

ROBERT S. LEVINE, MD, CHARLES H. HENNEKENS, MD, BARBARA KLEIN, MD, PEDRO L. FERRER, MD, JANET GOURLEY, BSNE, JANET CASSADY, MS, HENRY GELBAND, MD, AND MARY JANE JESSE, MD

Abstract: Blood pressure levels obtained on two occasions, one year apart, were evaluated among 212 children. An overall correlation of .65 was obtained for systolic pressure and .43 for diastolic pressure. The results suggest that adult levels of correlation are not reached in childhood and that screening programs must consider the relative lability of children's measurements in establishing referral criteria. (*Am J Public Health* 69:1175–1177, 1979.)

In adults, the risks[1, 2] and benefits[3, 4] from reduction of high blood pressure have been well described. Recent studies of hypertension in childhood[5–32] suggest prevalence rates of 0.9 per cent[7] to 13.4 per cent[5] with estimates of persistent elevation ranging from 0.6 per cent[5] to 2.5 per cent.[16]

The magnitude of this problem and the ability to reduce morbidity and mortality from persistent elevations in adults, suggests the possibility of developing preventive programs during childhood. To identify children at high future risk for hypertension as adults, however, requires a high predictive value of childhood pressures. The Pearson correlation coefficient,[33] a descriptive measure of the magnitude of association between blood pressure levels in the same individual measured at two different points in time, is one estimate of predictive value. In adults aged 35 to 70 years whose measurements were made four years apart, such correlations were approximately 0.6 for systolic and 0.4 for diastolic pressures at all ages.[34] Corresponding values for infants and children have been lower in each of several geographic locations.[35–39]

In this report we evaluate one year correlations for blood pressure among 212 white children in Miami, Florida. Of these, 101 were offspring of 42 men who had suffered a myocardial infarction (MI) before age 50 (cases), and 111 were children of 42 healthy men (controls). This evaluation includes the effects of age, gender, and body size as well as public health implications of these findings.

From the Departments of Pediatrics and Epidemiology, University of Miami School of Medicine. Address reprint requests to Dr. Robert S. Levine, Department of Pediatrics, University of Miami School of Medicine, P.O. Box 016820, MCCD #6021, Miami, FL 33101. (Dr. Hennekens is currently with Channing Laboratory and Peter Bent Brigham Hospital, Boston, MA.) This paper, submitted to the Journal January 5, 1979, was revised and accepted for publication May 10, 1979.

Methods

Detailed descriptions of the methods of procedure have been reported previously.[40, 41] At entry and one year follow-up, two blood pressure readings were taken five minutes apart on each child. In the following analyses, the mean of these two values was used. Diastolic pressure was taken to be Korotkoff sound IV. The one year Pearson product moment correlation coefficient was used to describe the association between blood pressure readings taken on the same child at these two points in time.[33] To evaluate the effect of gender and age upon these correlations, stratification by sex and five-year age groups was done. For body size, regression analysis was used; in this analysis, for each age-sex group, z-scores of weight/height^2 × 100 (Quetelet's Index[42]) were regressed on blood pressure z-scores, and correlations were recalculated using the residual values.

Results

The means and standard deviations for systolic blood pressure among male and female children of cases and controls at entry and one year follow-up are shown in Table 1. The mean pressures are very similar among children of men with and without MI, and no systematic differences are apparent among boys and girls. With the exception of diastolic pressure among children of cases, one year follow-up means are lower than entry means, a finding which is consistent with previous reports[34, 39] and which might reflect greater familiarity of participants with the study setting.

One year correlations of blood pressure among children of both cases (systolic = .61, diastolic = .43) and controls (systolic = .69, diastolic = .44) are all significantly greater than zero ($p < .001$). There are, however, no significant differences between correlations for children of cases and controls.

One year age- and sex-specific correlations for blood pressure levels are shown in Table 2. With respect to gender, the overall correlation for systolic pressure is identical among boys and girls (.65) while boys have a somewhat higher correlation for diastolic pressure (.47) than girls (.35). Age-specific correlations show no consistent trends for systolic or diastolic pressures.

Adjustment for body size (weight/height^2 ×100) gives a reduction in all overall age-specific correlations (Table 3). This positive confounding effect upon the correlations is most marked in the 0–4 year age group for both systolic (crude = .53, adjusted = .26) and diastolic pressure (crude = .58, adjusted = .39).

TABLE 1—Mean Blood Pressure Levels by Sex, Case—Control Status, and Time of Measurement

	Male Children of		Female Children of	
	Cases (n = 60)	Controls (n = 62)	Cases (n = 41)	Controls (n = 49)
Systolic BP*				
Entry	107 ± 11	109 ± 13	107 ± 11	105 ± 10
1 Year Follow-Up	106 ± 10	106 ± 13	104 ± 10	104 ± 10
Diastolic BP*				
Entry	64 ± 9	65 ± 9	64 ± 7	65 ± 9
1 Year Follow-Up	66 ± 8	64 ± 9	65 ± 8	63 ± 9

*mm.Hg ± Standard Deviation

TABLE 2—Correlations for Systolic and Diastolic Blood Pressure by Age and Sex*

	Systolic BP			Diastolic BP		
Age (yrs)	Boys	Girls	Total	Boys	Girls	Total
0–4	.44	.75	.53	.65	.41	.58
	(20)	(11)	(31)	(20)	(11)	(31)
5–9	.62	.48	.57	.45	.35	.38
	(33)	(25)	(58)	(33)	(25)	(58)
10–14	.71	.70	.71	.18	.42	.24
	(50)	(36)	(86)	(50)	(36)	(86)
15–19	.44	.54	.50	.69	.21	.44
	(18)	(15)	(33)	(18)	(15)	(33)
20–24	—	—	—	—	—	—
	(1)	(3)	(4)	(1)	(3)	(4)
TOTAL	.65	.65	.65	.47	.35	.43
	(122)	(90)	(212)	(122)	(90)	(212)

*Figures in parentheses indicate the number of subjects examined.

Discussion

These data show positive one year correlations for childhood blood pressure which are greater for systolic than diastolic pressures. There are no differences between mean levels of blood pressure for children of men with and without a prior MI, and in addition, the one year correlations are virtually identical. The values for boys and girls are also quite similar. Adjustment for body size, however, reduces the magnitude of all correlations, an effect which is most marked at the youngest ages, a period of rapid growth. This indicates that body size has a positive confounding effect on tracking correlations of childhood blood pressure and suggests that this variable should be considered in the assessment of blood pressure predictability during childhood. There is no consistent age pattern, but in general, the one year correlations for these children are lower than those reported in adults at four year intervals of follow-up. On the other hand, these correlations are generally higher than those reported from other studies of childhood populations.[36–39] This apparent discrepancy must be due, at least in part, to the shorter interval of follow-up in the present study since it has been shown that the magnitude of correlation decreases with increasing intervals between measurements.[38, 39]

These results have implications for the use of single casual measurements of blood pressure in screening programs of children. While blood pressure measurements in adults have been shown to be highly correlated with future cardiovascular disease,[43] long-term longitudinal studies relating single blood pressure measurements in childhood to future cardiovascular disease risk have not been done, and several short-term investigations[12, 16, 27, 30] among children have failed to confirm the adult findings. In the data of Clarke, et al.,[39] in fact, the probability of a child remaining in the highest quintile for repeated examinations at two year intervals was less than 20 per cent for systolic pressure and approximately 10 per cent for diastolic pressure after six years of follow-up.

TABLE 3—Correlations for Systolic and Diastolic Blood Pressure, Crude and Adjusted for Body Size (Weight/Height^2 × 100)

		Systolic Blood Pressure		Diastolic Blood Pressure	
Age (yrs)	N	Crude	Adjusted	Crude	Adjusted
0–4	29	.53	.26	.58	.39
5–9	57	.57	.53	.38	.38
10–14	85	.71	.67	.24	.21
15–19	33	.50	.40	.44	.42
TOTAL	204*	.65	.53	.43	.32

*8 of 212 children lacked measurement for weight and/or height.

In conclusion, these results strongly suggest that childhood screening programs should not rely on single determinations of blood pressure, both because of the likelihood of misclassification and since active intervention is not recommended for labile hypertension in childhood.[44] At the same time, the potential magnitude of the problem of childhood hypertension suggests the need for further evaluation of the short-term variability of blood pressure levels in children, in order to correctly identify individuals at increased risk as early in life as possible. As proposed by Rosner,[45] such evaluation should identify both the number of visits and measurements per visit required to achieve acceptable error probabilities.

REFERENCES

1. Society for Actuaries: Build and Blood Pressure Study. Vols. I and II. Chicago: Society of Actuaries, 1959.
2. Kannel WB, Dawber TR: Hypertensive cardiovascular disease: The Framingham Study, In Onesti G, Kim KE, Moyer JJ, (Eds)

Hypertension: Mechanisms and Management. New York: Grune and Stratton, pp 93-110, 1973.

3. Veterans Administration Cooperative Study Group on Antihypertensive Agents. Effects of treatment on morbidity in hypertension: results in patients with diastolic blood pressures averaging 115 through 129 mm. Hg. JAMA 202:1028-1034, 1967.
4. Veterans Administration Cooperative Study Group on Antihypertensive Agents: effects of treatment on morbidity in hypertension. II. results in patients with diastolic blood pressure averaging 90 through 114 mm. Hg. JAMA 213:1143-1152, 1970.
5. Rames LK, Clark WG, Connor WE, et al: Normal blood pressures and the evaluation of sustained blood pressure elevation in childhood: The Muscatine Study. Pediatrics 61:245-251, 1978.
6. Wilber JA: The problem of undetected and untreated hypertension in the community. Bull NY Acad Med 49:510-520, 1973.
7. Vital and Health Statistics. Data from the National Health Survey. Blood pressure of adults by race and area 1960-1962. Public Health Service Pub. No. 1000—Series 11, No. 5, 1964.
8. Londe S: Blood pressure in children as determined under office conditions. Clin Pediatr 5:71-78, 1966.
9. Heyden S, Bartel A, Haynes CG, et al: Elevated blood pressure levels in adolescents, Evans County, Georgia: seven year follow-up of 30 patients and 30 controls. JAMA 209:1683-1689, 1969.
10. Kilkoyne MM: Hypertension and heart disease in the urban community. Bull NY Acad Med 49:501-509, 1973.
11. Strotz CR, Shorr GI: Hypertension in the Papago Indians. Circulation 48:1299-1303, 1973.
12. Kilkoyne MM, Richter RW, Alsuf PA: Adolescent hypertension: I. Detection and prevalence. Circulation 50:758-764, 1974.
13. Kotchen JA, Schwertman KC, Kuller CH: Blood pressure distributions of urban adolescents. Am J Epidemiol 99:315-324, 1974.
14. Lauer RM, Connor WE, Leaverton PE, et al: Coronary heart disease risk factors in school children: The Muscatine Study. J Pediatr 86:697-706, 1975.
15. de Castro FJ, Bisbroeck R, Erickson C, et al: Hypertension in adolescents. Clin Pediatr 15:24-26, 1976.
16. Levine LS, Lewy JE, New MI: Hypertension in high school students: evaluation in New York City. NY State J Med 76:40-44, 1976.
17. Cretens ML: A hypertension screening program of children in Delta and Menominee Counties (Michigan). JAMA 32:216-217, 1977.
18. Garner WR, Gerald MC: Hypertension detection and results among young adults. JACHA 25:162-164, 1977.
19. Kimura T, Ota M: Epidemiologic study of hypertension: comparative results of hypertensive surveys in two areas in northern Japan. Am J Clin Nutr 17:381-390, 1965.
20. Tseng WP: Blood pressure and hypertension in an agricultural and a fishing population in Taiwan. Amer J Epidemiol 86:513-525, 1967.
21. Akinkugbe OO: School survey of arterial pressure and proteinuria in Ibadan, Nigeria. E Afr Med J 46:257-261, 1969.
22. Akinkugbe OO: Hypertensive disease in Ibadan, Nigeria: a clinical prospective study. E Afr Med J 46:313-320, 1969.
23. Johnson TO: Arterial blood pressures and hypertension in an urban African population sample. Brit J Prev Soc Med 25:26-33, 1971.
24. Ooi BS, Leonard KTT, Toh CCS, et al: Epidemiological studies of hypertensive disease in Singapore. Med J Aust 1:680-682, 1972.
25. Heyden S, Wolff G: Hypertonie bei jugendlichen. Med Monatsschr 29:9-11, 1975.
26. Laaser U, Schütt A, Kuschinsky G, et al: Kardiovaskulare riskofaktoren bei jungendlichen: erste ergebnisse der Kolner studie 1975/1976. Verk Deutsch Ges Inn Med 82 Pt 2:1148-51, 1976.
27. Weber MA, Stokes GS, Moses M, et al: Hypertension survey in a central free chest x-ray clinic: the Sydney hospital hypertension project. Med J Aust 2:529-533, 1973.
28. Bertrand E, Serie F, Kone I, et al: Etude de la prevalence et de certains aspects epidemiologiques de l'hypertension arterielle in Côte d'Ivoire. Bull Organ Mond Santé 54:449-454, 1976.
29. Hansen AT, Schnohr P, Sondergaard T: Oplysningskampagne om blodtrykkets betydning og kerunder maling af 30.000 blodtryk i hjerteugen 1975. Vgeskr Laegr 138:491-494, 1976.
30. Medina E, Quiroga J, Kaempffer AM: La hypertension arterial, un importante problema de salud publica. Rev Med Chile 104:486-490, 1976.
31. Rudnick KV, Sackett DL, Hirst S: Hypertension in family practice. CMAJ 117:492-497, 1977.
32. Cassimas C, Varlamis G, Karamperis S: Blood pressure in children and adolescents. Acta Paediatr Scand 66:439-443, 1977.
33. Snedecor GW, Cochran WG: Statistical Methods. Sixth edition. Ames, Iowa: Iowa State University Press, 1967.
34. Feinleib M, Halperin A, Garrison R: Relationship between blood pressure and age: regression analysis of longitudinal data. Paper presented at the 97th Annual Meeting of the American Public Health Association, Philadelphia, November 1969.
35. Levine RS, Hennekens CH, Klein B, et al: Tracking correlations of blood pressure levels in infancy. Pediatrics 61:121-125, 1978.
36. Zinner SH, Martin LF, Sacks F, et al: Longitudinal study of blood pressure in childhood. Am J Epidemiol 100:437-442, 1974.
37. Beaglehole R, Salmond CE, Eyles EF: A longitudinal study of blood pressure in Polynesian children. Amer J Epidemiol 105:87-89, 1977.
38. Rosner B, Hennekens CH, Kass EH, et al: Age-specific correlation analysis of longitudinal blood pressure data. Amer J Epidemiol 106:306-313, 1977.
39. Clarke WR, Schrott HG, Leaverton PE: Tracking of blood lipids and blood pressures in school age children: The Muscatine Study. Circulation 58:626-634, 1978.
40. Hennekens CH, Jesse MJ, Klein BE, et al: Cholesterol among children of men with myocardial infarction. Pediatrics 58:211-217, 1976.
41. Blumenthal S, Jesse MJ, Hennekens CH: Risk factors for coronary artery disease in children of affected families. J Pediatr 87:1187-1192, 1975.
42. Billewicz WZ, Kemsley WFF, Thompson AM: Indices of adiposity. Brit J Soc Prev Med 16:183-188, 1962.
43. Kannel WB, McGee D, Gordon T: A general cardiovascular risk profile: The Framingham Study. Am J Cardiol 38:46-51, 1976.
44. Report of the National Heart, Lung, and Blood Institute Task Force on Blood Pressure Control in Children. Pediatrics 59 (Suppl): 797-820, 1977.
45. Rosner B: Screening for hypertension—some statistical observations. J Chron Dis 30:7-18, 1977.