Diet and Hypertension

Gail Frank*

Hypertension – A Public Health Problem

Hypertension is a major public health problem of considerable magnitude. Based on the blood pressure level of 140/90 mm Hg, the National Health and Nutrition Examination Study I (NHANESI) estimates that 58 million Americans (55 million adults and almost 3 million children) are at increased risk of morbidity and premature mortality associated with high blood pressure, warranting some type of therapy or systematic monitoring (Table 1).

Among the noninstitutionalized adult population, the prevalence is higher for black persons compared with white at every age; for 35 to 54 year olds, the prevalence is almost twice as high. The male population has a higher prevalence than the female population until 65 years of age. The prevalence of hypertension among black women is almost twice that of white women.

Hypertension is one of three primary risk factors for both heart attack and stroke, which is the second major cause of cardiovascular death in the United States. Knowledge of how and when high blood pressure begins remains an unanswered research question.

Table 1. Prevalence Estimate for the Total U.S. Population 1983

Population Groups	*Prevalence* (In thousands)*
Adults (Ages 18 through 74 years, Civilian, Noninstitutionalized)	46,035
Institutionalized Ages 18 through 74 years	471
Military	312
Elderly (75 years and older)	8,710
Young (6 through 17 years)	2,724
TOTAL	57,712

*NHANES II & SHEP pilot rates
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*G. Frank, National Research and Demonstration Center-Arteriosclerosis, Louisiana State University School of Medicine, 1542 Tulane Avenue, New Orleans, LA 70112

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Etiology Complications

Blood pressure is the force of blood against the walls of the arteries and veins as the heart pumps. If arterioles or small arteries regulating blood pressure contract, restricting blood flow, then the heart must pump harder to force a blood flow. An increased blood pressure results. If it is sustained, then high blood pressure, or hypertension, results.

An increased, persistent workload of the heart and arteries due to high blood pressure creates ventricular wall tension and promotes left ventricular hypertrophy. Congestive heart failure can result. As pressure increases on the arterial wall, aortic aneurysm and angina can develop. Arterioles may disease and arteries lose their elasticity and hemorrhage. Scar tissue results. If clots become lodged in the small vessels, blood flow to the heart, brain or kidneys may be restricted, initiating a heart attack, stroke or kidney failure.

Ninety percent of the 58 million Americans with hypertension are diagnosed as having essential hypertension, for which the cause is unknown. About 10% of cases are due to a kidney abnormality, adrenal gland tumor or congenital defect.

The effects of hypertension are recognized by changes in the heart, kidneys and brain. Progressive changes in the retinal vasculature also define the severity of disease. Strokes and transient ischemic attacks reflect the cerebral effects of hypertension. Pathological studies indicate that hypertension promotes the progression of atherosclerotic lesions.

Methods of Measuring Blood Pressure

To study hypertension, one must obtain reliable blood pressure measurements. Several resources enumerate standardized procedures. Protocols from the Bogalusa Heart Study, Muscatine Heart Study, and several university-based surveillance studies provide details of the method. The American Heart Association Subcommittee of Postgraduate Education has published a booklet entitled, "Recommendations for Human Blood Pressure Determination by Sphygmomanometers." There are specific guidelines for measuring blood pressure in children and adults, as listed briefly below:

1. Blood pressures are measured in a quiet, nonthreatening environment with the person comfortably seated.
2. The person sits quietly for 5 to 10 minutes after recent activity, before the pressure is measured.
3. The pressures of infants and children younger than 5 years are measured while the child is supine.

4. An appropriately sized blood pressure cuff is used, with the bladder width 40% of the circumference of the limb.
5. Blood pressure instruments are well-lighted and the mercury column is at eye level.
6. The person's upper arm is fully exposed and resting on a supporting surface at heart level.
7. The 4th phase is recorded as the best measure of diastolic pressure.
8. Multiple blood pressure measurements or the average of two measurements are used as a representative level.
9. A well-trained observer should collect the blood pressure values.

Identification of the Hypertensive Person

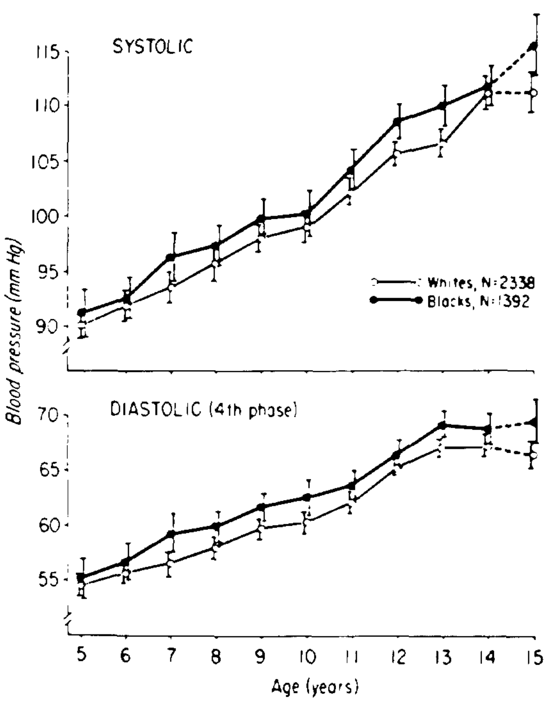
Once a procedure for collection of blood pressure data is standardized, blood pressure level becomes a direct indicator of hypertension.

What do we know about the natural history of blood pressure? Blood pressures for US children normally increase with age. In Bogalusa, Louisiana, we have observed the early natural history of hypertension during the past 13 years (Figure 1). There is a progressive increase of about 1.5 mm Hg systolic and 1 mm Hg diastolic pressure for each year of age. Black children have higher blood pressure than do white children. From 12 years of age until menopause, systolic pressures of the female are lower than those of the male.

In Bogalusa we have been so successful in creating a nonthreatening environment for taking blood pressure that the blood pressure levels of the children in our study are

Figure 1

Mean Blood Pressures of School Children By Age and Race (Bogalusa Heart Study)



lower than those of other studies and the levels given in the Task Force Report on Blood Pressure Control in children (Figure 2). We now have cohorts of children whom we have followed up for 12 years, from 14 to 26 years of age. We are able to study the transition of blood pressure and other cardiovascular risk factor variables across the adolescent and young adult age span.

The consistency of blood pressure level among children has been evaluated. Early in our study, blood pressures were measured for cohorts of children at either 5, 8, 11 or 14 years, then again one year later. The correlation of systolic blood pressures was higher than those of diastolic blood pressure. The correlations for systolic blood pressure observed were 0.64, 0.73, 0.61 and 0.62, respectively, illustrating a high association from one year to the next, irrespective of age. Correlation data of similar magnitude are reported for pediatric samples in a similar study in Muscatine, Iowa.

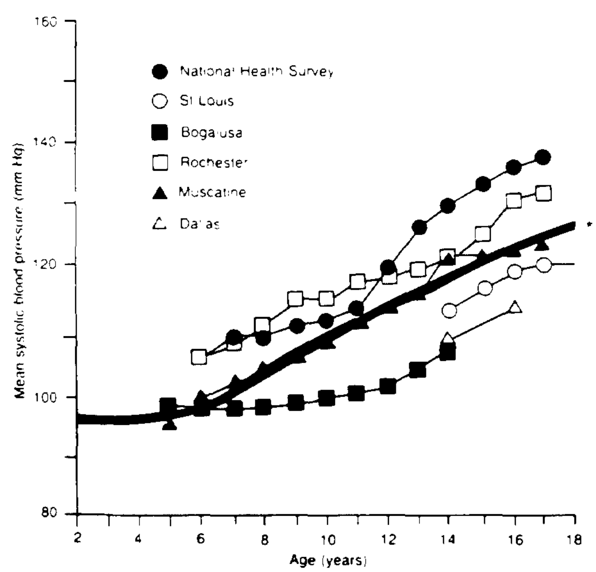
These observational studies suggest that a persistence of blood pressure rank in childhood occurs. If we can follow up these children to adulthood, then we can evaluate the likelihood that a child may remain in a certain track. This "tracking" phenomenon noted in childhood strengthens the argument for preventing or slowing the rise of blood pressure.

What level of blood pressure does one treat? Using the Joint National Committee definition of 140/90 mm Hg, we have identified the percentage of the adult population who would be treated. Thirty-eight percent of the black and 29% of the white meet or exceed this level. This represents 33% of men and 27% of women in the U.S.

Blood pressures were measured in a group of 650 high school students in Philadelphia using this same criterion. Initially, 8% of the freshmen, 11% of the sophomores and 16% of the juniors had elevated pressures, whereas, at 1 month reexamination, persistently high measures were observed for 3%, 5% and 6%, respectively. By 1 year the

Figure 2

Systolic Blood Pressure Levels for Boys by Age



Task Force on Blood Pressure Control in Children percentages with sustained elevation were 2%, 4% and 8%, respectively. One-fourth of the students were overweight and over half of the juniors had positive family histories of hypertension.

Applying the same criterion to freshmen, sophomores and juniors in Bogalusa, we found that no children in the first two classes had blood pressure above this level, possibly because of our study population's "normally" low blood pressures compared with other studies. Only 1% of the juniors met this criterion.

If we use a blood pressure level of 140/90 mm Hg to identify hypertensives needing treatment, then we will treat only a very small portion of the population. We will miss the borderline or mild hypertensive adult and the children who will potentially exceed the 140/90 mm Hg level in time. My personal belief is that hypertension should most appropriately be defined as that level above which investigation and treatment are more beneficial then harmful. This definition permits a freedom in treating any level that would likely promote target organ damage.

To "prevent hypertension" actually means to slow or to modulate the anticipated rise of blood pressure. Primary prevention demonstrates this approach. The purpose of primary prevention is to intervene into the natural evolution of the disease process before signs or symptoms appearing.

A primary prevention approach is a public health approach. If I wished to modulate the blood pressure levels of any group of people, I would view them as a population and use a primary prevention approach, preferably. If successful in creating behavioral changes that would lower blood pressure, then the mean blood pressure of this population might possibly shift to the left or decrease. Inter- and intravariability of blood pressure response would be great. Persons with the highest blood pressures might have the greatest decrease. Because their levels were the highest initially, they would have the greatest influence on the population mean. Persons in the top 10% to 20% of the blood pressure distribution, however, might be very resistant, both behaviorally and in blood pressure response; such persons become good candidates for the next stage of treatment.

Treatment of a clinically significant and persistent blood pressure level, such as 140/90 mm Hg or greater, is secondary prevention. Persons receiving secondary treatment are called "high risk."

To complete our model, a final stage of intervention is tertiary prevention, which is done after a heart attack or stroke. The purpose is to prevent further complications.

Primary Prevention

Risk Factors

It is generally accepted that a predisposition to essential hypertension is genetically determined. Essential hypertension occurs more frequently in children of hypertensive parents and in adult siblings of hypertensives. Observational studies suggest, however, that hypertension is associated with behavioral, social and environmental factors. These factors may trigger excessive reactivity of the sympathetic nervous system associated with elevations of blood pressure, and increases in heart rate, cardiac output and contractibility. Diet plays a dual role, both as a risk factor and as an intervention target for hypertension prevention.

Excessive sodium intake is the major dietary risk factor associated with blood pressure level. Population studies show a relationship between sodium intake and blood pressure. Difficulty in measurement of sodium intake is one of several factors that limit our ability to find an association between dietary sodium and blood pressure level for individuals and subgroups in populations. Major evidence, however, incriminates dietary sodium in the development of hypertension (Table 2).

In Japan, sodium intake averages 9 to 12 gm. There the incidence of hypertension among adults is 40% to 50% higher than in all other countries. In contrast, primitive tribes in the Amazon basin consume 2 gm of sodium daily and do not experience a rise in blood pressure with aging. As noted earlier for the U.S., in Westernized countries, blood pressure levels rise dramatically with each decade when the population is continually exposed to a high salt intake throughout life.

A few studies relate dietary sodium intake and blood

Table 2. Major Evidence Incriminating Dietary Sodium and Development of Hypertension

Source	*Observation*
Experimental	
Hypertensives	$\uparrow$ Concentration of Na+ in blood vessels and cells
	$\uparrow$ *Cardiac output linked with* $\uparrow$ blood fluid volume
	$\downarrow$ Na+ will lower blood pressure
Infants, Netherlands	Significantly $\downarrow$ blood pressure for 6 mo. infants on $\downarrow$ Na+ foods
Animal models	$\uparrow$ Na+ increases blood pressure in genetically predisposed animals
	$\uparrow$ Magnitude and early exposure of Na+ increases hypertension
Population	
General	Prevalence of hypertension correlates with Na+ intake
Specific	
Japanese, Japan	391-522 mEq/day Na+, Hypertension 40%-50% higher than any country
Yanomano Indians, Brazil	1 mEq/day Na+, Little or no hypertension
Solomon Islands	10-20 mEq/day Na+, Little or no hypertension
Samburu, Uganda	50 mEq/day Na+, Little or no hypertension
Bogalusa children, Louisiana	143 mEq/day, annual increase of blood pressure in biracial population

pressure in children. In a study conducted by Schachter and colleagues at the University of Pittsburgh, mothers of 6-month-old babies kept detailed diet records that were validated with chemical analysis of food. Systolic blood pressures of white infants who had increased sodium intakes had higher levels than 6-month-olds whose mothers had blood pressure above their age-specific levels but who had lower sodium intakes.

Hoffman and colleagues in the Netherlands tested the association between a low-sodium intake in infancy and subsequent blood pressure levels. Four hundred and seventy-six infants born to mothers with normal blood pressures were randomly assigned to one of two formulas and supplemental diets. One group of 245 infants consumed a diet with average sodium intake of 2.5 +/− 0.95 grams. The other 231 infants received a low-sodium formula and diet of 0.98 +/− 0.95 grams. All infants consumed the formulas for 6 months. After 25 weeks, a significant 2.0-mm difference in blood pressure was noted. Infants on the low-sodium formula had the lower blood pressures and also had a lower rate of increase in the blood pressure level. This study alerted us to the important role that sodium plays not only as a causal agent of high blood pressure, but also to the normal rise of blood pressure with growth and development in our Westernized society.

What is the effect of salt-loading on blood pressure? Carefully controlled salt-loading experiments have been conducted in select samples of adolescents. A recent study compared blood pressure increases before and after salt-loading in teenagers. One group of students had positive family histories of hypertension and were thereby at higher risk. Another group had labile blood pressures or vascillating high/low blood pressures, and a third group had normal blood pressures. After stressing students with a complex math problem, statistically significant increases in blood pressure were noted for both labile and genetically linked students (Figure 3).

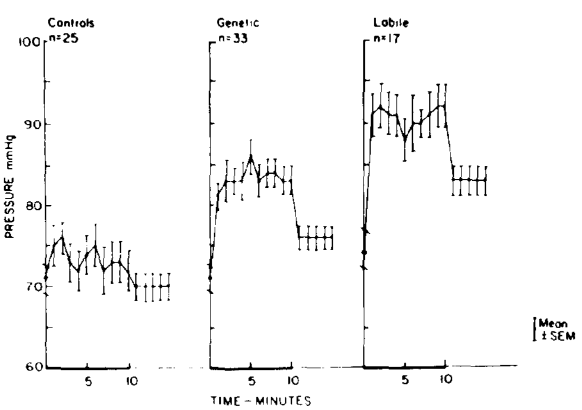
Electrolytes other than sodium, primarily potassium and calcium, are identified as having a role in blood pressure regulation via a naturetic effect. McCarron and colleagues analyzed the dietary and blood pressure data from the National Health and Nutrition Examination Survey I (NHANESI) and examined the association of 17 dietary components to blood pressure profile. They found that a significant decrease in calcium, potassium, vitamin A and vitamin C distinguished hypertensives from normotensives (Figure 4). This lower calcium intake was consistently noted for hypertensives.

Harlan and colleagues at the University of Michigan also analyzed NHANESI data. They noted an independent association between calcium, phosphorus, sodium/potassium ratio, alcohol intake and blood pressure (Table 3). The type of the associations was not the same for men as for women. For men, as calcium increased, then systolic blood pressure increased. For women, low levels of calcium were associated with higher levels of diastolic blood pressure.

Phosphorus had an inverse association with systolic blood pressure for whites and a positive association with diastolic blood pressure for blacks. The ratio of sodium to

Figure 3

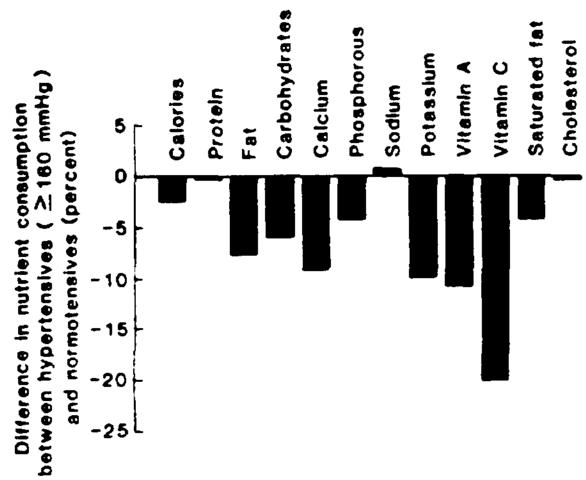
Change in Diastolic Blood Pressure During Stress in Adolescents



Falkner et al. Hypertension 3:521, 1981.

Figure 4

Standardized Mean Differences in Nutrient Intakes by Blood Pressure Level



McCarron et al., Science 224:1392-1398, 1984.

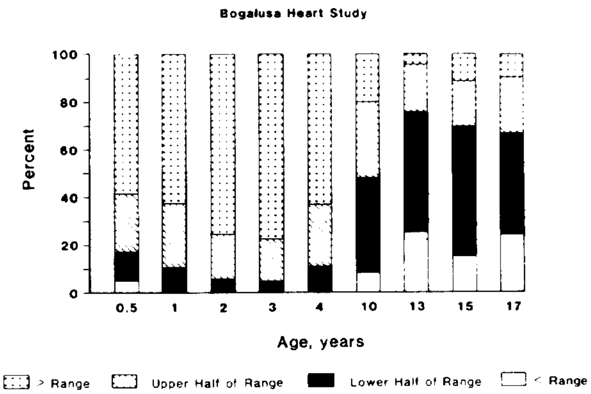
Table 3. Results of Univariate and Multiple Regression Analysis NHANESI Dietary and Blood Pressure Data

Dietary Component	*Direction*	*Group**
Calcium	+	Systolic; males
	−	Diastolic; females
Phosphorus	−	Systolic; whites
	+	Diastolic; blacks
Sodium/Potassium Ratio	+	Diastolic; males
Alcohol	U-shape	Systolic & Diastolic; male
	Curvilinear	Systolic & Diastolic; female

Harlan et al., J Epidemiol. 120:17-28, 1984.
*P<0.05

Figure 5

Comparison of Sodium Intake With Recommended Dietary Range For Several Cohorts or Children



potassium was related to diastolic blood pressure, but only in men. No significant association was found between sodium and blood pressure.

In univariate analysis, alcohol intake had a U-shaped association with both systolic and diastolic blood pressure. Those who drank less than 1 ounce (30 ml) of alcohol a week had lower pressures than abstainers or heavy drinkers (7 or more ounces, 210+ ml) per week. There was a positive association for men between heavy drinkers and blood pressure. For women, this positive association occurred only when alcohol intake was adjusted for body mass.

Gruchow and colleagues in Wisconsin also analyzed HANES data identifying sodium and alcohol intakes as the two major dietary components associated with elevated blood pressure. Calcium was much less important.

For our Bogalusa children, we do not find significantly lower calcium intakes for children with elevated blood pressures; however, dense sodium intakes are noted for all children.

Six and 12-month-old infants ingest 116 and 191 mg of sodium per kg of body weight, respectively, which corresponds to 6.4 to 10.6 gm of sodium a day in a 125-lb. adult female and 8.2 to 13.5 gm a day in a 160-lb. adult male.

We compared sodium intakes for infants and children from Bogalusa with the Recommended Dietary Range for sodium as proposed by the National Academy of Science, National Research Council (Figure 5). Among children 1 to 4 years old, about 90% exceeded the upper recommended range. For children 10 years of age and older, over 60% to 80% of the boys and girls exceed the upper range of sodium intake.

This excess sodium intake noted for Bogalusa children, but likely modeling larger populations of US children, structures a naturally occurring "salt-loading" experiment in our population.

The sources of sodium for children are primarily from vegetable and starch sources. For 10- and 13-year-old Bogalusa children, a greater percentage of sodium intake is provided at noon and evening meals from highly seasoned bean and vegetable dishes and bread and cereal products. Surprisingly, only one-fifth of the daily sodium intake comes from snacks (Table 4).

Table 4. Daily Sodium Intake (%) by Meal Snack Period for 10- and 13-Year-Old Children Bogalusa Heart Study

	Age		
Eating Period	*10 yrs. 1973*	*10 yrs. 1976*	*13 yrs. 1976*
		%	
Breakfast	14	15	19
Lunch	30	32	31
Dinner	37	32	43
Snacks	20	20	20

*Percentage based on children consuming meal or snack; accordingly, percent will not equal 100.

The reverse of the sodium picture was true for potassium intake. More children fell below the recommended range for potassium than above this range (Figure 6).

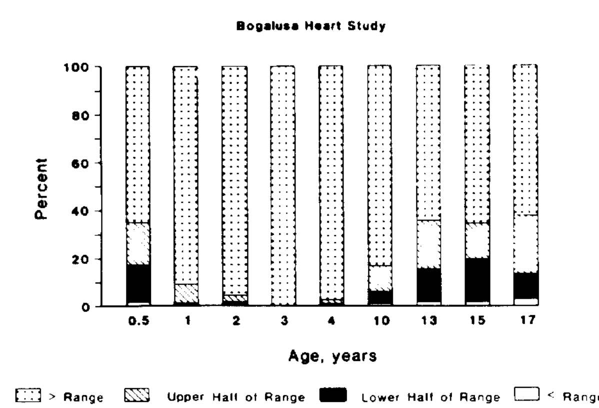
Clinical research studies at the University of Pittsburgh by Caggiula and colleagues are testing the hypothesis that daily increases in potassium with citrus fruit and bananas will lower the sodium-to-potassium ratio. Such dietary intake is not adverse to basic nutrition principles and may be much more practical an approach than attempts to lower sodium appreciably in the diet.

Recently, studies have shown that a reduction in dietary saturated fat intake, creating a polyunsaturated-to-saturated fat (P/S) ratio of greater than 1.0, lowers arterial blood pressure. Although exploratory work, this observation alerts us to multiple dietary approaches for potentially lowering the blood pressure level.

Obesity, which is diet-related, is considered a major risk factor for hypertension. The association of level of adiposity and blood pressure are influenced more by gain in weight rather than by the actual weight. Numerous studies of children and adults, such as Framingham adults, show positive correlation between weight gain and blood pressure. On the other hand, intervention studies for hypertension have shown that weight reduction alone and not in combination with a sodium restriction lowers blood pressure.

Figure 6

Comparison of Potassium Intake With Recommended Dietary Range For Several Cohorts or Children



Nonpharmacologic Treatment

Nonpharmacologic approaches to lower blood pressure are important in cases 1) where drug therapy is not effective, 2) where drug therapy produces disturbing side effects, or 3) when treatment compliance is low.

In the Hypertension Detection and Follow-Up Program (HDFP), 26% fewer deaths from all CV causes occurred among men receiving a stepped-care treatment of drug and diet with a 90 to 104 mm Hg baseline blood pressure than for those referred to regular care by their physician. The findings of the HDFP were extended to the next step of investigation by exploring the possibility of controlling blood pressure through nonpharmacological methods of weight reduction and sodium restriction, as demonstrated by Reisin. Persons whose blood pressures were controlled with medication and who were 120% or more above ideal weight were randomized to one of four conditions. These conditions were either medication continuation, no continuation and no intervention, no medication but a 70 mEq/day sodium restriction with increased potassium to 100 mEq/day, and no medication with a 20% weight reduction or achievement of ideal body weight.

Non-overweight controlled hypertensives were randomly assigned to one of the first three groups. All interventions consisted of 8 weekly sessions, followed by semimonthly individual sessions for 4 months and then monthly sessions for the remainder of the study.

The blood pressures of 59% of overweight hypertensives in the fourth group were under control 14 months after baseline measurements were taken. The blood pressures of only 35.5% of the control group with no dietary intervention and 44.9% of persons on the sodium-restricted regimen were under control. Fifty-three percent of the non-overweight on sodium restriction achieved blood pressure control compared with 45% of the nontreatment group. Of the mild hypertensives who were overweight, the blood pressures of 72% of those on weight reduction were under control compared with 52% not on treatment. The blood pressures of 78% of persons on sodium restriction were under control compared with 58% under control in the group not on sodium restriction. This study showed that successful dietary treatment can control blood pressure without medication.

Table 5. Dietary Recommendations to Control Hypertension

1. Control obesity
   - increase energy expenditure
   - participate in aerobic exercises
   - reduce fat intake and approach P/S - 1.0
2. Moderate sodium intake to 2 to 3 grams of sodium a day
3. Limit alcohol intake to 1 to 2 servings per day
4. Achieve Recommended Dietary Range for potassium and RDA for calcium.

Summary

What then should be our dietary recommendations to prevent or control hypertension? As shown in Table 5, we should strive to control obesity through increased energy expenditure, moderate aerobic exercise and reduced fat intake, which should approach a P/S of 1.0. Sodium intake should be restricted to 2 to 3 grams per day and alcohol intake limited to 1 to 2 servings per day. In addition, we should try to achieve the Recommended Dietary range for potassium and RDA for calcium.

Figure 7

PLEDGES TO AID DIETARY SODIUM REDUCTION FOR CHILDREN AND PARENTS - ADAPT

ADAPT PLEDGES-CHILD

1. ____ I pledge to taste my food first before adding any seasoning.
2. ____ I pledge to not add salt to any food I eat.
3. ____ I pledge to not buy or eat
   - ____ regular ketchup
   - ____ pickles, olives
   - ____ potato chips, fritos
   - ____ salted popcorn
   - ____ hot dogs
   - ____ luncheon meat
   - ____ ham
   - ____ bacon
   - ____ sausage
4. ____ I pledge to use my counter booklet to see how much salt I eat.
5. ____ I pledge to ____________________.

Signature: ____________________ Date: __________

Witness: ____________________

ADAPT PLEDGES-PARENT

1. ____ I pledge to remove and keep the salt shaker off my kitchen/dining room table.
2. ____ I pledge to reduce the amount of salt added to foods during cooking.
3. ____ I pledge to not buy or serve any of these foods to my child/family.
   - ____ salt, salt substitute
   - ____ regular ketchup
   - ____ pickles, olives
   - ____ potato chips, fritos
   - ____ salted popcorn
   - ____ hot dogs
   - ____ luncheon meat
   - ____ vegetables with salted meats
   - ____ canned vegetables (unless rinsed)
   - ____ ham
   - ____ bacon
   - ____ sausage
4. ____ I pledge to use low-sodium ____________ instead of regular ____________.
5. ____ I pledge to try ____ (number) new low-sodium recipe(s) such as __________ during the next week.
6. ____ I pledge to modify my favorite recipe to low-sodium.
7. ____ I pledge to ____________________.

Signature: ____________________ Date: __________

Witness: ____________________

There are no "10 easy steps" to achieve these dietary goals. The reality of all our research efforts is that our experimental and epidemiologic research must continue, but our daily living cannot be put into limbo while we wait for all the answers. We have a great deal of control over our dietary, exercise and alcohol behaviors. The food and restaurant industries can respond by giving us choices.

Here are examples of ways we have tried to influence dietary behavior. In an intervention program in Franklinton, Louisiana, we worked with seven restaurants to lower sodium content of certain entrees, thus allowing 50 children whose blood pressures persisted at the 90th percentile or above to have some choice of the sodium content of foods when eating out. Students were taught to read labels during a clinic setting, and we continue to provide students with a knowledge base for decision-making, by teaching students to read and evaluate the heart-healthy nature of foods in science classes in the New Orleans area.

In complementing student attempts at healthy eating behaviors, parental support is crucial, so we have provided classes on low-sodium cooking procedures. And students practice taking small steps to behavioral change by making a commitment, and marking on pledge sheets to actively change eating behavior (Figure 7). Parents sign similar pledges to support their child's behavioral changes (Figure 7). We have noted significantly lower sodium intakes for children as their pledging activities increase.

These types of behavioral changes are needed early in life and throughout life to modulate blood pressure levels and influence the natural history of hypertension.

We should all be encouraged to promote our blood pressure health with dietary modifications. There are indications from research and observation studies as to which dietary components have an important role in the hypertension process. The challenge is to target our eating behaviors to change and begin. Fifty-eight million Americans are at risk. Our combined efforts are needed to alter the course of hypertension.

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