AN EPIDEMIOLOGICAL STUDY OF PRIMARY HYPERTENSION IN CHILDREN AND ADOLESCENTS 5 TO 18 YEARS OF AGE IN A RURAL NEWFOUNDLAND COMMUNITY

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by

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ABSTRACT

An epidemiological study of primary hypertension in children and adolescents attending school in a rural Newfoundland community was carried out in 1977. Blood pressure measurements of 320 subjects 5 - 18 years of age were taken with a Physiometrics Automatic Blood Pressure Recorder. Of these 320 subjects, 68 had had their blood pressure measured two years earlier with an Arteriosonde 1010 recorder. The blood pressure values of these 68 subjects were used to study the "tracking" of blood pressure by plotting a scattergram and obtaining linear regression statistics.

Subjects were grouped into two year age groups and their blood pressure readings adjusted for age and sex and expressed in standard deviation unit (SDU) or scores.

SDU scores ≥ 1 to <2 were considered as "high normals" and used to identify prospective hypertensives. SDU scores ≥ 2 were used to identify hypertensives.

The familial aggregation of blood pressure was studied using the Analysis of Variance (ANOVA) technique.

Blood Pressure readings for two year age groups were correlated with eleven factors. These were: height, weight, Quetelet Index, triceps skinfold thickness, subscapular skinfold thickness, upper arm circumference, resting heart rate, amplitude of P wave in lead II, amplitude of R wave in lead II, family size and birth order.

Multiple linear regression analysis was carried out for children in the 5 - 12 and adolescents in the 13 - 18 year age groups. This division was made to ascertain whether the determinants of

blood pressure levels might be different for children and adolescents. Blood pressure in SDU was the dependent variable and the eleven factors listed above were the independent variables. The data on three of these independent variables, height, weight and Quetelet Index were converted to SDU. The level of statistical significance was chosen as $p \leq 0.05$.

The following results were obtained:

(a) 14.4% of the 320 subjects had "high normal" systolic blood pressure with SDU scores ≥ 1 to <2 and 15.3% had "high normal" diastolic (4th phase) blood pressure with SDU scores ≥ 1 to <2. 1.6% had systolic hypertension with SDU scores ≥ 2. 1.6% had diastolic hypertension with SDU scores ≥ 2.

(b) There was a strong significant tracking of systolic blood pressure. The regression coefficient of follow-up systolic blood pressure on initial systolic blood pressure was 0.53 ($p < 0.00002$). A significant tracking effect of diastolic (4th phase) blood pressure was also obtained. The regression coefficient of follow-up diastolic (4th phase) blood pressure on initial diastolic (4th phase) blood pressure was 0.19 ($p < 0.05$).

(c) A significant aggregation of systolic ($p < 0.01$) and diastolic ($p < 0.01$) (4th phase) blood pressure within families was found for subjects 5 - 18 years of age.

(d) Correlation analysis showed that systolic blood pressure was positively correlated with amplitude of P wave in lead II and amplitude of R wave in lead II in all age groups of each sex. Diastolic (4th phase) blood pressure was positively correlated with height, triceps skinfold thickness, resting heart rate, amplitude of P

wave in lead II and amplitude of R wave in lead II in all age groups of each sex.

(e) Multiple linear regression analysis showed that resting heart rate and amplitude of P wave in lead II were significant positive predictors of both systolic and diastolic (4th phase) blood pressure in the 5 - 12 and 13 - 18 year age groups. The amplitude of the R wave in lead II was a significant positive predictor of systolic blood pressure in the 5 - 12 and 13 - 18 year age groups.

The findings relating amplitude of P wave in lead II and amplitude of R wave in lead II to blood pressure levels in children and adolescents is, to the author's knowledge, new and have never been reported before.

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CHAPTER 1

INTRODUCTION

EPIDEMIOLOGY OF PRIMARY HYPERTENSION

Definition of Primary Hypertension

The term primary hypertension is, by definition, high blood pressure without evident cause. It is used to describe those individuals with raised arterial pressure for which no apparent etiology can be delineated. Other terms used to refer to primary hypertension are hyperpiesis, essential hypertension, or hypertension without evident cause.

Consequences of Primary Hypertension

Cardiovascular epidemiological studies (1, 2, 3, 4) have shown that primary hypertension is a serious mass public health problem among the adult population in technologically advanced societies. Furthermore, it is acknowledged that people with primary hypertension are at an increased risk of experiencing major morbid cardiovascular events, espectially heart failure, heart attack, stroke, and kidney failure with resultant chronic illness and disability. It has also been noted that young and middle aged adults with primary hypertension are at increased risk of dying prematurely from cardiovascular complications (5).

Blood Pressure Levels in Children and Adolescents

The observation that primary hypertension in the adult population is very common, and that if untreated, can cause major

cardiovascular problems, has led researchers to consider the significance of blood pressure measurements in children and adolescents. These measurements of blood pressure levels in children and adolescents have shown that there is a continuous increase in blood pressure levels throughout the school age years (6) and that primary hypertension does exist in children and adolescents (7).

However, there are few epidemiological studies which have attempted to identify the factors that might be responsible for this observed increase of blood pressure levels with age, and the existence of primary hypertension among the young.

Identification of Future Hypertensives in Childhood

If primary hypertension does have its onset in childhood, then it would be extremely important to be able to identify the prospective or actual hypertensive patients at an early age since this would allow for the possibility of early intervention. This kind of approach would have economic, sociological, as well as medical advantages.

Methods That Can be Used to Identify Hypertensives and Future Hypertensives in Childhood

It would be possible to identify these prospective or actual hypertensives by observing how their blood pressure levels differ from others belonging to their own age and sex group. It has been suggested (8) that young subjects who have blood pressure values ≥ 1 to < 2 SDU above the mean of their age and sex group be considered as having "high normal" blood pressure levels and those who have blood pressure levels ≥ 2 SDU above the mean of their age and sex group be considered as hypertensives.

It should be pointed out that this criteria is not meant to be a clinical definition of hypertension, only an epidemiological one which can be used to express the prevalence of hypertension.

The identification of prospective hypertensives can also be done by studying the familial aggregation of blood pressure. This approach was taken by Zinner and Kass (9) who found a clustering or aggregation of blood pressure among children 2 to 14 years of age.

Another important epidemiolgical consideration is whether blood pressure taken on previous occasions continue along the same "track" that is, high for age or low for age, in later years. If this is the case, then this would be another way of identifying future hypertensives in childhood. Those studies which have attempted to study the phenomenon of "tracking" of blood pressure (10, 11) have concluded that stratification of blood pressure within peer groups begins and is detectable in childhood.

It would also be important to find out what descriptive variables are associated with the observed blood pressure levels in children and adolescents and to ascertain the predictive power of these variables. The identification of these variables would have implications for prevention of primary hypertension both at the secondary and primary levels.

With these considerations in mind, it was decided to embark on a study of the blood pressure levels of children and adolescents attending school in a rural Newfoundland community with the following major objectives.

OBJECTIVES OF THE STUDY

1. To obtain normative data for blood pressure measured in a non-clinical setting of children and adolescents in Newfoundland and

to compare, where possible, this with other data reported in studies done in Canada, the United States and other countries.

2. To identify hypertensive subjects as well as those subjects with blood pressure levels which indicate a tendency towards primary hypertension later on in life for later continual follow-up.
3. To ascertain whether genetic and/or environmental factors are associated with the observed levels of blood pressure, and at the same time attempt to identify which factors might be predictors of high blood pressure levels.
4. To investigate the "tracking" of blood pressure levels of subjects who were studied two year earlier in order to determine whether they remained in the same class of blood pressure frequency distribution.
5. To establish a cohort of subjects which could be followed prospectively in order to evaluate how their blood pressure levels change as they approach adulthood.
6. To suggest and institute measures which might help those who show a tendency towards becoming hypertensive and to evaluate the effectiveness of these measures in the later follow-up.

In the following Chapter a review if made of the relevant literature concerning primary hypertension in children and adolescents.

CHAPTER 2

REVIEW OF THE LITERATURE

INTRODUCTION

The review of the literature pertaining to hypertension in children and adolescents will be dealt with under five main sections. These are:

1. The Methodology of Blood Pressure Measurements;
2. Prevalence of Primary Hypertension in Children and Adolescents;
3. "Tracking" of Blood Pressure
4. Familial Aggregation of Blood Pressure
5. Factors Associated with Blood Pressure Levels in Children and Adolescents.

SECTION 1

The Methodology of Blood Pressure Measurements

This section will deal with the method used in measuring blood pressure in epidemiological studies. Mention will also be made of possible errors that can occur through the use of the method and how these errors can be minimised.

a) Measurement of Blood Pressure

In epidemiological studies, blood pressure is usually taken with a mercury manometer, an inflatable cuff and a stethoscope. The blood pressure is measured from the bare upper arm with the cuff applied evenly and firmly with the lower edge about 2 cm above the crease of the elbow. The brachial artery is palpated with the arm stretched out fully with the hand supinated, and the stethoscope placed over the

artery.

The cuff should be inflated rapidly to about 30 mmHg above the anticipated level of the systolic blood pressure and then deflated at a rate of about 2 to 3 mmHg per second while auscultation is performed over the brachial artery. The cuff pressure at which the sounds are first heard is the systolic pressure which corresponds to the first Korotkoff sound, after which the sounds are prolonged into a murmer - phase II, which corresponds to the second Korotkoff sound. The third phase (third Korotkoff sound) occurs when the sounds become clearer and increase in intensity. This is followed by a dull and then muffled sound which is the phase IV diastolic. The latter is equivalent to the fourth Korotkoff sound which later disappears. The disappearance of the sound is the fifth phase diastolic which corresponds to the fifth Korotkoff sound.

b) Recording of Blood Pressure

Readings are recorded as systolic, diastolic phase IV and diastolic phase V blood pressure. However, it is recommended that the diastolic phase IV be recorded for children and adolescents (12). The reason the fourth phase is suggested as a better index of diastolic blood pressure is that the Korotkoff sounds, in this age group, can be heard when the cuff is completely deflated.

c) Errors which can be made when Measuring Blood Pressure with a Mercury Manometer

It is important to note that blood pressure measurements taken with a mercury manometer using an inflatable cuff and stethoscope are subject to certain errors:

(i) an unconscious observer preference for certain terminal digits, usually 0 or 5;

(ii) reading back to the point of visual oscillations from that at which the auscultatory end-points occur, with over-compensation;

(iii) the possibility of pressure values being forgotten between the moment of reading and tabulation;

(iv) the examiner's behaviour and the circumstances surrounding the measurement;

(v) auditory problems that the examiner might have.

d) Deviation in Blood Pressure Readings

Voors *et al* (13) have suggested that at the higher range of pressures, the true blood pressure may be higher than that obtained with the mercury manometer. They made this suggestion after surveying nine studies. They found that in these studies (14 - 22), the direction of the deviation of systolic blood pressure readings obtained with one mercury manometer was similar to the deviation they obtained using a similar mercury manometer. In 7 of these 9 studies the deviation of diastolic (4th phase) blood pressure readings was similar to theirs. They took blood pressure measurements obtained with a Physiometrics Automatic Blood Pressure Recorder as the true pressure.

They claimed that this deviation in blood pressure readings obtained with the mercury manometer was apparently due to the human ear not being able to detect the first infrasonic signals (23, 24) of the arterial wall vibration (25) as the cuff pressure approaches the systolic pressure from above. They also stated that true blood pressures in the lower range may be equal to or lower than mercury manometer pressures. Their reasoning was that for the mercury manometer, an

excess pressure reading is caused by the compliant motion of the periarterial tissues (26) and that under low cuff pressure corresponding to low intra-arterial pressure, these tissues will move relatively easily, but that this compliance will be impeded under high cuff pressure - corresponding to high intra-arterial pressures (27).

e) Advantages of the Physiometrics Automatic Blood Pressure Recorder

The Physiometrics Automatic Blood Pressure Recorder (Figure 1) is an electronic infrasonic device which records the blood pressure on a paper disc rotated by an aneroid manometer in open communication with an over-size rubber cuff bladder (35 cm long and 12 cm wide) entirely encircling the upper arm. This cuff bladder fits all arms including those of children and obese adults and because of its ample size it avoids excess blood pressure readings.

Because the Physiometric Automatic Blood Pressure Recorder senses the fundamental phenomena of arterial flow under an occluding cuff, it eliminates the potential errors inherent in auscultative measurements such as the examiner's hearing acuity, the stethoscope used, and the dependence of subsequent readings on previous ones that have been known to occur in the conventional audio-visual recordings of blood pressure made with mercury manometers.

In addition, blood pressure measurements made with the Physiometrics Automatic Blood Pressure Recorder is not subject to systematic errors such as digital preference and inter-observer bias. A permanent record of the blood pressure reading is obtained which can be interpreted and read to one millimeter accuracy by the examiner. The speed with which the cuff is inflated and deflated can be fixed in this instrument.

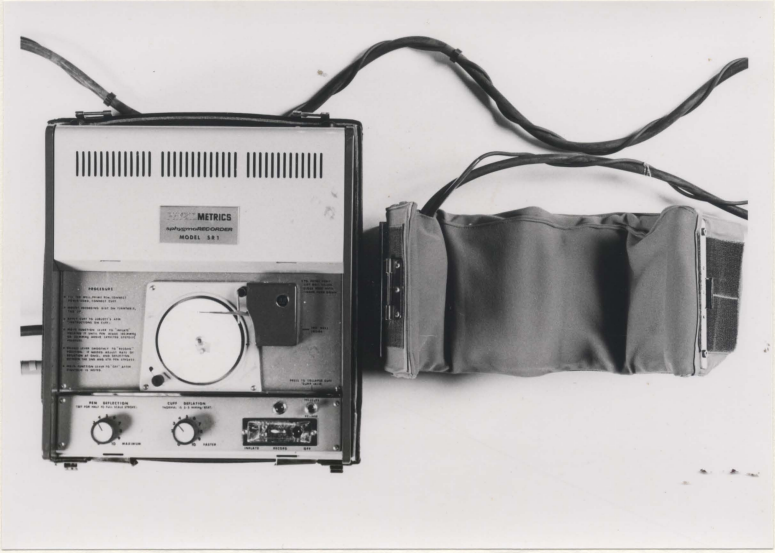

FIGURE 1

PHYSIOMETRICS AUTOMATIC BLOOD PRESSURE RECORDER WITH CUFF

It has also been shown by Voors *et al* (13) that greater reliability was achieved with the Physiometrics Automatic Blood Pressure Recorder than on the mercury manometer (Baumanometer) for each age when measuring blood pressure of children 5 to 14 years of age.

f) Errors in Blood Pressure Reading Due to Inappropriate Cuff Size

The selection of an appropriate cuff size to be used with the mercury manometer is also essential for recording accurate blood pressure readings in children and adolescents. (Cuff size refers only to the inner inflatable bladder, not to the cloth covering.)

In studies of direct and indirect readings of blood pressure in infants and older children, Woodbury, Robinow and Hamilton (28) and Robinow *et al* (29) concluded that the smaller the arm, the narrower the cuff should be. Karvonen, Telivuo, and Järvinen (30) drew attention to another factor which could influence blood pressure readings. In a comparison of direct and indirect readings in 53 subjects they found that too short a cuff bladder may, like too narrow a cuff, produce artificially high readings.

Similarly, King (14) and Simpson *et al* (31) found that low indirect pressure readings resulted from the use of cuffs which were wider and longer than standard. King (14) also found that too short a blood pressure bladder produced artificially high readings, but concluded that once the cuff had encircled the arm, the effect of the cuff length on the reading was minimal. He stressed the importance of these findings for pediatric studies. In another study, Long, Dunlop and Holland (32) found that factors such as upper arm length, arm circumference and skinfold thickness did not have very much influence

on the level of blood pressure recorded in children. However, they found that in the same child, when cuffs of differing size were used, smaller cuffs gave consistently higher readings.

It is possible to minimise the errors in cuff selection by using the largest cuff which will snugly fit the subject's arm. In addition, the inflatable bladder contained within the cuff should completely encircle the arm without overlapping. The cuff used with the Physiometrics Automatic Blood Pressure Recorder meets these requirements.

The inflation of an improperly applied cuff may also result in systematically high readings (33). Variations in the speed of cuff inflation and deflation may result in differences in recorded pressures (19). The Physiometrics Automatic Blood Pressure Recorder eliminates this problem because the rate of inflation and deflation of the cuff is fixed in this instrument.

g) Preparation of the Subject Before Blood Pressure Measurement

Apart from the use of mercury manometers, inflated cuffs and stethoscope, together with the inherent potential errors which can result when they are used to measure blood pressure in children, is the very important aspect of proper preparation of the child or adolescent for accurate determination of blood pressure.

This can be done by allowing sufficient time for the child or adolescent to recover from any recent activity or apprehension. If this is not done, then erroneous blood pressure levels will be recorded. Also the procedure should be fully explained and stressful circumstances eliminated whenever possible. The subject should be in a comfortable sitting position with the right upper arm fully exposed and resting on

a supportive surface at heart level (34).

SECTION 2

Prevalence of Primary Hypertension in Children and Adolescents

Although there were studies which had reported blood pressure levels in children and adolescents before 1970 (35 - 39), it was not until the early 1970's that researchers doing these studies began to focus their attention on the possibility that blood pressure levels obtained in children and adolescents might be indicative of primary hypertension in this sector of the population. Because of this, epidemiological research into primary hypertension in children and adolescents has increased. Furthermore, it is now apparent that the frequently stated belief that primary hypertension was rarely found in childhood and that most cases of hypertension in children were of a secondary nature was not quite true.

a) Prevalence of Primary Hypertension in Children and Adolescents Reported by Londe

Perhaps the single most important study to point out the prevalence of primary hypertension in children and adolescents was that reported in 1966 by Londe *et al* (7). In this study, 74 children and adolescents between the ages of 4 and 18 years who were otherwise asymptomatic, had supine blood pressure values which exceeded standards previously established for normal children (40, 41). These children belonged to middle to low income families. All blood pressure readings were taken under office conditions by Londe from the right arm using a mercury manometer and either an open-bell stethoscope, or the open side of the pediatric size Littman stethoscope.

Various cuff sizes were used depending on which width most closely approximated two-thirds of the length of the upper arm. The cuff was completely deflated between readings. If the patient was crying the blood pressure was not taken. Diastolic blood pressure was recorded at the disappearance of the 5th Korotkoff sound; if this was not possible then the 4th Korotkoff sound was recorded. Londe's definition of hypertension was systolic and/or diastolic pressures repeatedly above the 90th percentile and occasionally above the 95th percentile during the course of at least one year.

These children were followed for at least one year, and for an average of 3 1/2 years during which time they were investigated for possible causes of blood pressure elevations. These investigations, annual physical examinations and laboratory studies, failed to indicate a possible cause for hypertension in all but 5 of these children. Seventeen of the 74 had primary hypertension before they were 6 years of age and all but 2 of the hypertensives were below 15 years of age.

Londe also reported that 53% of these 74 hypertensive children were overweight as compared to a group of 74 matched normotensive subjects in whom the incidence of obesity was only 14%. This difference was highly significant ($p < 0.01$). Family histories obtained for 54 of the hypertensive children showed that 24 of these 54 hypertensive children had one parent with hypertension, whereas only 9 of 50 control families had such a history. This was also a highly significant difference ($p < 0.01$).

Although Londe's subjects were a selected group from his private clinical practice, his study showed that children younger than 6 years of age can have primary hypertension. This finding

contradicted the previously held belief that primary hypertension was rare in children. He also found that hypertensive children were more likely to have at least one hypertensive parent. Another significant finding of his study was that hypertensive children were more likely to be obese.

b) Factors Which Could Affect the Reported Prevalence of Primary Hypertension in Children and Adolescents

Other researchers (Table 1) have also shown that primary hypertension exists in subjects 4 - 20 years of age. As shown in Table 1, the prevalence of primary hypertension reported in the studies reviewed ranged from 0.6% to 4.4%. The prevalence of systolic hypertension ranged from 1.2% to 8.9%. For diastolic hypertension the prevalence ranged from 2.4% to 12.2%. However, several factors complicate the determination of the magnitude of the problem in this age group.

In some of these studies, different criteria were used for establishing the presence of hypertension. Some researchers (6, 42, 8) used a reading of $\geq$140 mmHg systolic and/or $\geq$90 mmHg diastolic, another (43) a reading of $\geq$150 mmHg systolic and/or $\geq$95 mmHg diastolic and others (44,7) readings >95th percentile to indicate the presence of primary hypertension. In some studies (44, 7) blood pressure were taken by more than one examiner.

Blood pressure measurements were also taken in different positions. The sitting position was the most common (6, 42, 43), however, the supine position was also used in one study (7). In one study done in 1965 by Kumura and Ota (45) the point of muffling (4th phase diastolic) was taken as the diastolic pressure, in other studies

TABLE 1

PREVALENCE OF PRIMARY HYPERTENSION IN CHILDREN AND ADOLESCENTS

AUTHOR & Yr. Published	REF. NO.	POPULATION	ETHNIC BACKGROUND	AGE(yrs)	METHOD OF MEASUREMENT	CRITERIA USED FOR HYPERTENSION (mmHg)	PREVALENCE OF HYPERTENSION %
CASSIMOS et al 1977	44	4,428 school children 2,223 males 2,205 females	Greeks	7-18	One examiner; position not stated, right arm, diastolic = 5th phase	>95th percentile	14-18 yrs. 3.1%
LAUER et al 1975	6	4,829 school children 2,346 boys 2,483 girls Muscatine, Iowa, U.S.A.	96.4% white 0.6% black 2.8% Spanish American 0.1% Oriental 0.1% American Indian	6-18	More than one examiner; sitting, both arms - average of two readings used, diastolic = 4th phase	≥140 and/or ≥90	8.9% systolic 12.2% diastolic 4.4% systolic and diastolic
REICHMAN et al 1975	42	1,863 students N.Y., U.S.A.	1,449 black 388 white 26 Oriental, American Indian, etc.	12-20 90%(14-17)	More than one examiner; sitting, left arm, diastolic = 5th phase	≥140 and/or ≥90	5.9% systolic 2.5% diastolic
SILVERBERG et al 1975	43	15,594 high school students Edmonton, Albt. Canada	Not stated	15-20	More than one examiner, sitting, right arm, diastolic =5th phase. If no disappearance was detected, the point of muffling was used	≥150 and/or ≥95	2.2%
KILCOYNE et al 1974	8	3,537 high school students, Harlem New York, U.S.A. Follow up 7-10 days later of those with elevated blood pressure	2,193 black 124 white 1,220 Latin	14-19	More than one examiner; sitting left arm, diastolic = 5th phase	≥140 and/or ≥90 ≥140 and/or ≥90	5.4% systolic 7.8% diastolic 1.2% systolic 2.4% diastolic
LONDE et al 1966	7	1,473 outpatients 735 boys, 738 girls St. Louis, Missouri U.S.A.	Not stated	4-15	One examiner; supine, right arm, diastolic = disappearance - if not possible, then muffling of the sounds	>95 percentile	2.3%
KIMURA & OTA 1965	45	2,728 students 1,255 males 1,473 females Japan	Japanese	0-19	Number of examiners - not stated; position not stated; right arm, diastolic = 4th phase	≥160 and/or ≥95	0.6%

(44, 42, 8) the point of disappearance (5th phase diastolic) was taken as the diastolic pressure.

Blood pressure was recorded from the right arm in some studies (44, 43, 7, 45). In others it was recorded from the left (42) and in one study (6) blood pressure was recorded from both arms and the average of two readings used to designate the blood pressure level. The amount of time the subject spent in a given position and the time which elapsed between blood pressure measurements was seldom stated. The cuff size used to measure blood pressure was not always reported. The effect which inappropriate cuff sizes can have on blood pressure readings was mentioned in Section I of this Chapter.

These different methods which have been used to obtain blood pressure measurements from subjects make it difficult to compare the prevalence of primary hypertension reported in these studies mentioned above and summarised in Table 1. Perhaps the most important difference was the use of different definitions of blood pressure levels for identifying young hypertensives. It is quite reasonable to assume that the levels, $\geq$140 mmHg and/or $\geq$90 mmHg; $\geq$160 mmHg and/or $\geq$95 mmHg which are levels recommended to designate "borderline hypertension" and hypertension respectively in adults (46) were employed because of a lack of data to specify what constitutes abnormal blood pressure levels among children and adolescents.

c) Prerequisites for Establishing Abnormal Blood Pressure Levels in Children and Adolescents

In order to specify what values of blood pressure reading are abnormal in children and adolescents, it would be necessary to have published values for blood pressure levels at various ages based on

similar methodologies. However, at the present time this is not possible since there are very few studies which have documented blood pressure levels at different ages in children. In addition, those studies which have reported blood pressure measurements made in children tended to use different methodologies (Table 1) to obtain their measurements.

Also most of these studies were cross-sectional. Consequently, it would therefore require studies which investigate whether children and adolescents continue to "track" at the same blood pressure level with time, in order to establish meaningful values.

d) Criteria Suggested for Designating Abnormal Blood Pressure Levels in Children and Adolescents

Perhaps the criteria which would be most useful in designating primary hypertension in children and adolescents at this point of the research into hypertension in children and adolescents would be that suggested by Kilcoyne (8). Her suggestion was based upon the finding after using the preselected value of $\geq$140 mmHg systolic and/or $\geq$90 mmHg diastolic to designate hypertension. She found the value of $\geq$140 mmHg used to designate systolic hypertension was two and one-half standard deviations above the observed mean of the systolic blood pressure in females and only one and one-half standard deviations above the mean systolic blood pressure in males. Thus, there was a discrepancy between the commonly selected value of $\geq$140 mmHg and the observed mean of the systolic pressure.

She suggested that in order to incorporate these variations anyone with a value of 1 standard deviation above the mean should be remeasured. Subjects with blood pressures in excess of 2 standard

deviations above the mean should be carefully evaluated and followed up longitudinally. She contends that because there is very little information available in the literature which describes the evolution of hypertension which has its onset during adolescence, the adoption of a standard which is related to the mean of the pressure observed in children and adolescents to designate hypertension would yield more meaningful information. Based on the preceding suggestions, it was decided that in this study blood pressure values ≥ 1 to <2 standard deviation units (SDU) above the mean of a subject's age and sex group will be considered as "high normals". Blood pressure values ≥ 2 SDU above the mean of a subject's age and sex group will be designated as hypertensive.

e) Definition of Standard Deviation Units (SDU) or SDU Scores

The SDU equals the subject's blood pressure minus the mean blood pressure for his or her age and sex group divided by the standard deviation of the blood pressure in that group.

Summary

In summarising this section of the review, one finds that primary hypertension does exist in children and adolescents in greater numbers than was once thought. Londe's study (7) which was done with careful attention to details pointed this out. Other studies (Table 1) have also supported this finding. However, in these studies (Table 1) there was a tremendous variation in methods used to obtain blood pressure measurements from subjects. These variations in methods could have affected the reported prevalence of primary hypertension in this sector of the population.

Methodological variations included blood pressure measurements being taken by more than one examiner, recorded from different arms and in different positions. The recording of 4th phase diastolic blood pressure in some studies, and the recording of 5th phase diastolic blood pressure in other studies also contributed to the differences in methodology which made comparison of results among studies inappropriate.

In most of the studies reviewed the criteria used to define primary hypertension in children and adolescents was that recommended to define primary hypertension in adults. It is a well known fact that blood pressure levels, within the normal limits, for children and adolescents are quite different from those of adults, so the use of adult levels to indicate the presence of primary hypertension in children and adolescents was inappropriate. In view of this, it was suggested that SDU values be used as a criteria to designate abnormal blood pressure levels in children and adolescents.

In all of the studies reviewed, blood pressure measurements were made with mercury manometers. The bias inherent in the taking of blood pressure measurements with these instruments was mentioned above, together with errors in blood pressure recordings which stem from the use of inappropriate cuff sizes. It was pointed out that these disadvantages can be overcome by using the Physiometrics Automatic Blood Pressure Recorder to take blood pressure measurements.

SECTION 3

"Tracking" of Blood Pressure

It is assumed that once a person's blood pressure has

entered a certain "track" (e.g. high for age or low for age), it tends to continue along that "track" with time so that higher blood pressures tend to remain higher and lower blood pressures tend to remain lower (48). Investigating the "tracking" of blood pressure is useful since it allows for a better understanding of the natural history of blood pressures in children and adolescents. It also permits early identification of those who are most likely to become hypertensive later in life. This, in turn, can lead to the institution of preventive measures.

a) Study by Zinner *et al*

Zinner *et al* (49) did such an investigation of 609 children whose blood pressures were measured four years earlier. These children were 2 - 14 years of age at the time of the initial study. All blood pressure measurements were taken with the Kass-Mollo-Christensen portable automated blood pressure recorder which minimises observer error. This instrument generates a paper tape of the blood pressure recording which forms a permanent record.

Blood pressures were taken after each subject had sat quietly in a chair for 5 minutes. Three readings were taken and the mean of these three readings used for subsequent calculations. As was the case in the initial study, blood pressures were adjusted for age and sex and expressed as standard deviation units (SDU). As was pointed out earlier, the SDU equals the subject's pressure minus the mean pressure for his or her age and sex group divided by the standard deviation of the blood pressures in that group. Age groups were stratified at two-year intervals.

When follow-up SDU scores were compared with initial SDU

scores it was found that of 88 children with initial systolic scores greater than 1.0 SDU above the mean, 57 (65%) of these children had positive SDU scores at the follow-up survey. Of 81 children with initial systolic scores less than 1.0 SDU below the mean, 57 (70%) had negative scores at follow-up.

Regression analysis of the follow-up blood pressure on the initial blood pressure showed a significant positive relation of follow-up to initial systolic and diastolic blood pressures. This study indicated that there was a significant tendency for blood pressure scores to "track" in the pattern exhibited four years earlier in these children.

Other studies (50, 51, 52, 53) have also demonstrated the "tracking" of blood pressure.

Summary

These studies represent an important epidemiological finding by suggesting that blood pressures taken in childhood may be predictive of blood pressure levels in adulthood. If this is the case, then studies of the "tracking" of blood pressure can be useful in helping to identify potential hypertensives.

SECTION 4

The Familial Aggregation of Blood Pressure in Childhood

Numerous studies have documented the importance of family history in the development of primary hypertension in childhood (54, 55, 56, 7) or in later life (57, 58).

a) Study by Zinner *et al*

Zinner *et al* (9) using the same instrument and procedures as described on page 20, obtained blood pressure measurements from 721

children 2 - 14 years of age. Using SDU scores (see page 20), and the technique of analysis of variance (ANOVA), these researchers showed that in 176 families consisting of two or more children, there was a significant ($p < 0.01$) aggregation or clustering of blood pressures within the family. This was the case for both systolic and diastolic blood pressures. In a follow-up study four years later (49) analysis of variance again revealed the variance of systolic and diastolic blood pressures within families to be significantly less ($p < 0.001$) than among families.

The results of this study indicate that aggregation of blood pressure occurs in families of children as young as 2 years of age. Furthermore, this familial clustering continued to exist 4 years later. Lee *et al* (59) and Klein *et al* (60) suggested that familial blood pressure relations can be demonstrated at birth or in the early months of life.

b) Study by Biron *et al*

In another study (61), Biron *et al* investigated the familial resemblance of blood pressure in natural children versus adopted children of French Canadian extraction. This study was undertaken between 1972 and 1974. It included 398 families with at least one adopted child.

Blood pressures were measured by a nurse using a standard mercury sphygmamonometer fitted with a constant deflation valve. Different cuff sizes were used for children and the first and fourth Korotkoff sounds were used to identify the systolic and diastolic blood pressures, respectively. All readings were taken in the seated position, with exceptions occurring when the child was too

young to sit still. In such cases the blood pressure was taken in the supine position.

Blood pressures were taken in a random order. Two readings were taken and averaged to obtain single values for systolic and diastolic blood pressures, respectively. SDU scores of blood pressures were calculated using 3 year age intervals for boys and girls and 10 year age intervals for fathers and mothers. A "midparent" score was calculated for parents of each family by averaging the mother's and father's scores. Pearson's correlation coefficient was calculated using the "midparent" score and a natural or adopted child's score chosen at random. The correlation coefficient obtained was squared to give the coefficient of determination R^2, which expresses the proportion of the variance of the children's pressure that is "explained" by that of the parents.

Correlations of child - child blood pressure scores were calculated by choosing at random a pair of natural children or a pair of adopted children in homes with more than one child of the same status. There was more than one natural child in 80 homes and more than one adopted child in 138 homes.

The results of this study showed blood pressure of natural children resembled to a small but significant extent that of their natural parents and that of their natural brothers and sisters. This finding was not reproduced for adoptive children who showed no significant resemblance of blood pressure either with their adoptive parents or their adoptive brothers and sisters, with whom they shared the family environment.

Summary

In reviewing the literature relevant to this section, one finds that there are few studies of familial aggregation of blood pressure involving observations made in children. This may have been the case because of the idea that blood pressure measurements in children are unreliable or difficult to obtain. However, Zinner (9, 49) and Biron (61) have shown that such measurements in children are possible.

Measurements of blood pressures in children will allow investigators of primary hypertension to examine the familial relationship of blood pressure in childhood with a view to finding out its possible relevance to the onset of primary hypertension. This will also permit the possible identification of hypertensive families.

SECTION 5

Factors Associated with Blood pressure Levels in Children and Adolescents

a) Age and Sex

Several studies (50, 9, 43, 10, 6) show that systolic and diastolic blood pressure in children and adolescents increase with age. In one study (50) of Polynesian children resident in New Zealand, it was also shown that mean systolic blood pressure was slightly higher in girls than in boys, for most single age groups in the range 5 - 14 years of age. Exceptions occurring in boys 7, 9 and 10 years of age whose mean systolic blood pressure was slightly higher than girls. Girls 5, 6, 8, 10, 11, 12, 13 and 14 years of age had higher diastolic (4th phase) blood pressure than boys the same age. Boys 7 and 9 years of age had slightly higher diastolic (4th phase) blood pressure levels than girls.

Blood pressures in this study were taken by one examiner with a Sphygmomanometer, using two different cuff sizes. The number of blood pressure readings taken and the arm from which they were taken was not mentioned. The position in which blood pressure was taken was also not stated. The method used to determine the ages of these children was not indicated.

In another study, Zinner *et al* (9) found that girls in the 2 - 3, 8 - 9, 10 - 11, and 12 - 14 age groups had higher mean systolic pressure levels than boys. Boys in the 4 - 5 and 6 - 7 age groups had slightly higher mean systolic blood pressure than girls. Girls had mean diastolic (4th phase) blood pressure levels which were higher than boys in all the age groups (2 - 3, 4 - 5, 6 - 7, 8 - 9, 10 - 11, and 12 - 14) studied.

In this study blood pressure was taken in the home with a blood pressure recorder which minimises observer error and allows for standardisation of blood pressure readings. Parent's blood pressures were taken followed by children's; each person's blood pressure was taken three times in succession after the subject had been seated in a chair for 5 minutes or longer. The mean of the three readings was used. This study like the one before (50) did not state how the ages of the children were verified. No mention was made from which part of the body these blood pressures were recorded. The ethnic background of the group studied was not indicated.

Silverberg *et al* (43) found that boys 15 - 20 years of age had higher mean systolic blood pressure values than girls of the corresponding ages. However, girls had higher mean diastolic blood pressure levels than boys in all age categories.

In this study, blood pressures were taken by more than one examiner, using mercury manometers with blood pressure cuffs of different lengths and widths. The diastolic blood pressure was taken at the point where the Korotkoff sounds disappeared. If these sounds did not disappear then the point at which they became muffled was taken as the diastolic blood pressure. Blood pressure measurements were made in the right arm in the seated position.

The amount of time spent in the seated position before blood pressure was recorded was not mentioned; also, the number of readings done on each person was not documented. As was the case in the two previous studies (50, 9) the method used to identify the ages of the subjects was not stated. The ethnic background of the students who participated in this study was not documented.

Another study by Zinner *et al* (10) showed that males in the 5 - 7, 8 - 9, 14 - 15, and 16 - 20 age groups had higher mean systolic blood pressure levels than females. Females in the 10 - 11 and 12 - 13 age groups had higher mean systolic blood pressures than boys. Higher mean diastolic (4th phase) blood pressure levels were found in males belonging to the 8 - 9 and 10 - 11 age groups. Girls in the 5 - 7, 12 - 13, 14 - 15, and 16 - 20 age groups had higher mean diastolic (4th phase) blood pressure levels than boys of the corresponding age groups.

The participants in this study were blacks and whites. Blood pressures were taken using the same instruments and method as described on page 20. No information was given with regards to the part of the body from which the blood pressures were taken. The method used to verify ages of the children who took part in this study was

not indicated.

Summary

In summary, these studies (50, 9, 43, 10) show that systolic and diastolic blood pressure have a tendency to increase with age. The relationship between sex and blood pressure show than mean systolic blood pressure was generally higher among girls 5 - 14 years of age. However, in one study (10) boys in most age groups had higher systolic blood pressure than girls in the 2 - 14 year age range. In a study of adolescents 15 - 20 years of age it was found that males in all age groups had higher systolic blood pressure than females (43).

It would appear from the results reported in these studies that on the whole girls are more likely to have slightly higher systolic blood pressure than boys in the 5 - 14 year age group. However, as shown in the study by Zinner (10), this is not always true. Among adolescents the tendency was for males to have higher systolic blood pressure than females of all age groups. So it does appear from the results of these studies that as the sexes get older there is a distinct difference in systolic blood pressure levels, with males having higher systolic blood pressure readings.

In the case of diastolic (4th phase) blood pressures, it was apparent that in most cases there were no consistent differences between the sexes up to about 14 years of age. However, in one study (9), girls did have higher diastolic (4th phase) blood pressure than boys in all age groups up to 14 years of age. In the older age groups it was reported (43) that females in all single age groups 15 - 20 years

of age had higher diastolic (5th phase) blood pressure levels than their male counterparts.

From the results of these studies it appears as if there are no consistent differences in diastolic (4th phase) blood pressure between the sexes before 15 years of age, after which females seem to have higher diastolic (5th phase) blood pressure readings than males of the same age.

While such findings have been reported in these studies, it is important to point out that the methods used to obtain the relevant data were quite variable. Blood pressure measurements were made by more than one examiner in some situations. Also, different instruments were used to measure blood pressure. Some studies used the 4th phase, while others used the 5th phase diastolic signal to report diastolic blood pressure.

The number of blood pressure readings taken, the part of the body from which it was taken, and the position of the subject when the blood pressure measurement was made was not always stated. The amount of time the subject spent in a particular position before the blood pressure was taken was seldom reported. The time which elapsed between blood pressure measurements was also not mentioned. In all the studies there was no indication of what method was used to verify the ages of the subjects. In addition, the age groups used to report blood pressure measurements tended to be different in most studies.

Anthropometric Factors and Blood Pressure

In 1975 Lauer *et al* (6) used the ponderal index which is height (inches) divided by $\sqrt[3]{\text{weight (pounds)}}$ and triceps skinfold thickness as indicators of obesity for males and females 6 - 18 years

of age. Negative correlations were reported between ponderal index and systolic and diastolic blood pressures, respectively. Positive correlations 0.39 and 0.36 between triceps skinfold thickness and systolic and diastolic blood pressures respectively were also reported. Height was positively correlated with systolic (0.55) and diastolic (0.44) blood pressures. Weight was also positively correlated with systolic (0.60) and diastolic (0.49) blood pressures (6).

Height was measured in the standing position using an anthropometric planewith the subject in stocking feet. Body weight was measured using a beam-type scale calibrated with standard weights and the subject clothed and shoeless. Blood pressures were measured with mercury-filled sphygmomanometers by more than one examiner. Different sizes of cuffs were used, with the subject in the seated position. Blood pressures were recorded from both arms and the average of the two readings used for analyses. Of those studied, 96.4% were white, 0.6% were black, 0.1% were American Indian, 0.1% were Oriental and 2.8% were Spanish Americans (6).

In this study by Lauer *et al* (6), triceps skinfold thickness was measured with a Lange skinfold caliper. The skinfold was taken at the measured mid-point between the acromion and the tip of the elbow over the triceps muscle of the left arm. The arm was hanging straight and in a relaxed condition. Three measurements were made and the mean of these used for analyses.

This study did not state how long the subject was seated before his/her blood pressure was taken, and the time interval which elapsed between the taking of blood pressure from one arm and the next. Mention was not made as to how the ages of the subjects were

determined. Also, the number of examiners involved in the measurements of height, weight, and triceps skinfold thickness was not stated.

Stine *et al* (62) reported positive correlations of the magnitude .32 and .34 between triceps skinfold thickness and systolic and diastolic blood pressure respectively for males 7 - 9 years of age. For females in the same age group, the correlations were .27 and .28 for triceps skinfold thickness and systolic and diastolic blood pressure, respectively. Males in the 10 - 12 year age group had correlations of .23 and .35 between triceps skinfold thickness and systolic and diastolic blood pressures respectively. Females belonging to the 10 - 12 year age group had correlation values of .34 and .35 for triceps skinfold thickness and systolic and diastolic blood pressures respectively.

Males 7 - 9 and 10 - 12 years of age had correlation coefficient values of .34 and .43 between weight and systolic blood pressure. For diastolic blood pressure the correlation was .35 and .22 between weight and diastolic blood pressure for males in the 7 - 9 and 10 - 12 year age groups, respectively. Females 7 - 9 and 10 - 12 had correlations of .32 and .38 between weight and systolic blood pressure. For diastolic blood pressure and weight the correlations were .24 and .37 for females 7 - 9 and 10 - 12 years of age, respectively.

In this study (62) skinfold measurements were done by more than one technician using procedures standardised by test-retest measurements. The skinfold was measured with Lange Calipers over the triceps muscle picked up on half of the distance between the acromion and the olecranon processes, not including muscle tissue.

Blood pressure measurements were taken from the left arm with aneroid sphymomanometers with the children seated. The fifth

phase diastolic was taken as the diastolic blood pressure reading. Children were weighed in stocking feet and underclothes on standard school scales. Scales were balanced before each weighing session.

This study by Stine *et al* (62) did not state what procedures were used to standardise the test-retest measurements in taking skinfold measurements made on each individual. The amount of time the subject spent in the seated position before blood pressure was taken was not stated. In this study, as well, there was no mention of the method used to ascertain the ages of the subjects.

Miller and Shekelle (63) found white males in the 15 - 16 year age group to be taller and heavier than white females in the same age group. However, their mean body mass index (kg/m^2) was almost the same -- 21.5 for males and 21.1 for females. Mean triceps skinfold thickness for males in the same age group was 10.6; for females the mean triceps skinfold thickness was 16.9.

Correlations between triceps skinfold thickness and systolic blood pressure were .22 and .18 for males and females, respectively. Correlations between triceps skinfold thickness and diastolic blood pressure were .07 and .11 for males and females, respectively. The correlation between body mass index (kg/m^2) and systolic blood pressure was stronger for males than females -- .29 versus .21. In the case of the correlation between diastolic blood pressure and body mass index. (kg/m^2), males had a correlation coefficient of .10 and females .09. Multiple linear regression analysis showed a significant ($p < 0.001$) association between body mass index (kg/m^2) and systolic and diastolic blood pressures. For systolic blood pressure on body mass index, the regression coefficient was .29 for males and .20 for females. For

diastolic blood pressure on body mass index, the regression coefficient was .10 for males and .08 for females.

A single casual blood pressure reading was taken after the subject had been lying on a cot for five to ten minutes during which time heart sounds were evaluated. A standard mercury sphgymomanometer was used in conjunction with a cuff which covered at least two-thirds of the upper right arm. The first and fifth phase of the Korotkoff sounds were used to indicate systolic and diastolic blood pressures respectively.

Weight was measured on a beam balance with the subject wearing indoor clothing, but without shoes. Height was measured with the subject standing erect and the head positioned so that the eye-ear plane was horizontal, with heels back and against a vertical surface. A rectangular box was placed firmly in contact with both the top of the head and a scale fixed to the vertical surface in order to obtain the height.

W/H^2 (where W - weight in kg and H - height in meters) was used to compute body mass index. This index (W/H^2) provides a measure of weight corrected for height. In this study it was stated that triceps skinfold thickness was measured with Lange Calipers using the procedures described by Selzer and Mayer (64). Measurements of blood pressure, weight, height, and triceps skinfold thickness were made by more than one examiner.

No mentioned was made in this study as to what method was used to verify the ages of the participants.

Voors *et al* (13) using both the mercury sphygmomanometer and the Physiometrics Automatic Blood Pressure Recorder to take blood pressure measurements found that among the variables that consistently

provided contributions to the variation in blood pressure were ponderosity index (weight/height^3), body height, and sex.

The results of the study (13) showed that the regression coefficients for height and systolic blood pressure were respectively for Baumanometer and Physiometrics, .28/.36 ($p < 0.001$), and for the male sex and systolic blood pressure 1.17/2.08 ($p < 0.001$ and $p < 0.0001$). Also, regression coefficients for height and diastolic blood pressure was .26 ($p < 0.0001$) and for ponderosity index (wt/ht^3) 12.95 ($p < 0.0001$) for blood pressure measured with Physiometrics Automatic Blood Pressure Recorder.

In this study (13), 35% of the study population were black and 63% were white. The children ranged in age from 5 - 14 years.

As mentioned above, two instruments, the mercury sphygmomanometer (Baumanometer) and the Physiometrics Automatic Blood Pressure Recorder were used to take blood pressure. Different bladder sizes were used for the Baumanometer cuff based on arm measurement criteria recommended by Karvonen *et al* (30), Simpson *et al* (31) and King (14).

The examiners involved in blood pressure measurements were trained and tested before the study, as well as four times during the study. Training and testing were done using 1) the sound film, "Practice in Blood Pressure Reading" (National Medical Audiovisual Center at the Center for Disease Control, Atlanta) and 2) a cuff with a Y-shaped tube leading to two Baumanometers, and a stethoscope with Y-shaped tubes leading to two sets of earpieces. This method allowed blind measurements to be made by two observers on the same subject at the same instant.

Children were encouraged to void before their blood pressures were taken. Nine blood pressure measurements were made on each child by three observers in a randomised sequence. Two of these observers used a mercury Baumanometer, the other used the Physiometrics Automatic Blood Pressure Recorder. The blood pressure was taken from the right arm with the child seated. Systolic and diastolic (4th phase) blood pressures were used in the analysis of the data.

This study did not state how long the subject was in the seated position before his blood pressure was taken and the time interval between the taking of blood pressure measurements. The report of this study by Voor *et al* (13) did not state how weight and height were measured. Also, the method used to ascertain the ages of the children in this study was not indicated.

Pulse Rate

Miller and Shekelle (63) in their study (described on page 32), found that there were statistically significant ($p < 0.05$) correlations between pulse rate and blood pressure (systolic and diastolic), for both white males and white females. For systolic blood pressure the correlations with pulse rate were .32 and .36 for males and females respectively. For diastolic blood pressure the correlations with pulse rate for males and females were .09 and .18 respectively.

The pulse rate was obtained from a thirty-second count of the resting radial pulse. The method used to determine blood pressure levels in these children was described on page 32.

Summary

In these studies (6, 62, 63, 13), different methodologies were used to obtain and analyse the data collected. Therefore, the results reported in these studies cannot be compared with one another. Some of the differences in method include position of the subject when blood pressure was taken, the number of readings taken, and the diastolic signal used to indicate diastolic blood pressure. Also, the grouping of subjects into age groups tended to differ among studies.

Bearing these differences in mind, a summary of the results reported in these studies is presented in Tables 2 and 3.

APPROACH TO THE PROBLEM

It was evident from the review of the literature that primary hypertension is more prevalent in children and adolescents than was once thought. However, it was also apparent that the criteria used to identify subjects as hypertensive in this age group varied among studies (Table 1). In most studies (6, 8, 42, 43, 45), blood pressure levels used to designate adults as being hypertensive were used to label children and adolescents as hypertensive. In other studies (7, 44), blood pressure levels greater than the 95th percentile were used as the criteria for designating primary hypertension.

As stated above most studies used recommended adult levels of blood pressure (Table 1) to designate the presence of hypertension in children and adolescents. Since it is recognised that children and adolescents tend to have lower blood pressure levels than adults it would seem that the use of adult criteria to designate hypertension in the young is likely to underestimate the problem.

TABLE 2

RESULTS OF CORRELATION BETWEEN BLOOD PRESSURE AND

ANTHROPOMETRIC VARIABLES REPORTED IN VARIOUS STUDIES

AUTHOR & YR. PUB.	REF. NO.	AGE GROUP	ANTHROPOMETRIC VARIABLE	SYSTOLIC B.P.	DIASTOLIC B.P.
Lauer *et al*, 1975	6	6-18 (males & females)	Ponderal Index (ht/3 wt)	-	-
			Height	+	+
			Weight	+	+
Stine *et al*, 1975	62	7-9 (males)	Triceps Skinfold	+	+
		7-9 (females)	Weight	+	+
		10-12 (males)	Triceps Skinfold	+	+
		10-12 (females)	Weight	+	+
Miller & Shekelle, 1976	63	15-16 (males)	Triceps Skinfold	+	+
		15-16 (females)	Weight	+	+
			Pulse Rate	+	+

TABLE 3

MULTIPLE REGRESSION ANALYSIS FOR BLOOD PRESSURE OBTAINED WITH PHYSIOMETRICS AND BAUMANONOMETER FOR CHILDREN AGED 5 - 14 YEARS [VOORS *et al* (Ref. 13)] AND FOR BLOOD PRESSURE OBTAINED WITH BAUMANOMETER FOR ADOLESCENTS 15 - 16 YEARS [MILLER & SHEKELLE (REF. 63)]

STUDY BY VOORS *et al*	SYSTOLIC BLOOD PRESSURE	p	DIASTOLIC BLOOD PRESSURE	p
HEIGHT				
Physiometric	0.28	<0.0001	0.26	<0.0001
Baumanometer	0.36	<0.0001		
PONDEROSITY INDEX (wt/ht^3)				
Physiometric	46.36	<0.0001	12.95	<0.0001
Baumanometer	31.46	<0.0001		
MALE SEX				
Physiometric	1.17	<0.001		
Baumanometer	2.08	<0.0001		
STUDY BY MILLER & SHEKELLE				
BODY MASS INDEX (wt/ht^2)	0.29	<0.001	0.10	<0.00
Baumanometer - Males	0.29	<0.001	0.10	<0.001
- Females	0.20	<0.001	0.08	<0.001

In order to specify what are abnormal blood pressure values in children and adolescents it would be necessary to have published values of blood pressure levels at various ages. However, at the present time such data are not available because the number of studies which have investigated blood pressure levels in children and adolescents at various ages have been few.

It was decided, therefore, that for the purposes of this research, the most useful criteria for designating primary hypertension in children and adolescents would be that based on a standard which is related to the mean of the pressures observed in children and adolescents. In view of this, blood pressure values ≥ 1 to <2 standard deviation units (SDU) above the mean will be considered as "high normal", and blood pressure values ≥ 2 SDU above the mean will be designated as hypertensives.

In all of the studies reviewed, blood pressure was measured with mercury manometers. However, as was pointed out in the Literature Review, measurements of blood pressure with these instruments are subject to a number of systematic errors, including inter-observer variation, digit preference, that is the tendency for readings to cluster around zeros and fives, or just below the cut off point of arbitrary significance. Errors can also be made by using an incorrect size or improperly applied cuff. In this study, blood pressure measurements will be made with a Physiometrics Recorder which eliminates these errors which are inherent in the use of mercury manometers. The Physiometrics Automatic Blood Pressure Recorder also has other advantages over the mercury manometer which have been mentioned in the review of the literature.

The review of the studies indicated that there was a great deal of variation in the methods used in obtaining blood pressure measurements from subjects. Some researchers took blood pressure readings with the subject in the supine position, others with the subject in the seated position. Blood pressure readings were taken from the right arm in some studies, while in others it was taken from the left arm. In some studies the 4th Korotkoff sound was used to indicate the diastolic blood pressure; in other studies the 5th Korotkoff sound was used. It was recommended by Kirkendall *et al* (12) that the 4th Korotkoff sound be used to indicate diastolic blood pressure. The amount of time the subject spent in a given position before the blood pressure was taken was seldom mentioned. In cases where multiple measurements were made the time interval between measurements was not indicated. The method used to obtain and verify the ages of subjects was seldom mentioned.

Since the factors mentioned above can play a significant role in accurately determining blood pressure levels, it is important that special attention be paid to them. However, as can be seen from the Review of the Literature, many studies did not take these factors into account. It is hoped that this study will be an improvement on the methodology used in obtaining blood pressure measurements.

Studies reviewed in the literature (9, 49, 61) also indicated that there was a tendency for blood pressure to cluster or aggregate within families. The results of these studies seem to indicate that primary hypertension is an inherited disorder which may be unmasked by a variety of environmental factors. Thus, the possibility of identifying those children within families which show an aggregation

of blood pressure would allow for preventive action to the undertaken.

The "tracking" of blood pressure levels over time, as indicated in the Literature Review, can be a very important epidemiological method which can be used to identify future hypertensives. The feasibility of this method is supported by Miall and Lovell (48) who suggested that changes of pressure with time is related to the level of pressure attained and that, once elevated, blood pressure tends to remain elevated and to rise more strikingly than blood pressures closer to the mean.

In reviewing the literature, one finds that there is a lack of information with regards to factors which might be responsible for elevated blood pressure levels and primary hypertension in children and adolescents. Since primary hypertension is thought to have a multi-factorial etiology it is well worth while investigating factors which might lead to this condition later in life. In addition, primary hypertension in young people is more common than previously realised and because of its inevitable long-term complications, dealing with this problem constitutes a vital form of preventive medicine.

SPECIFIC AIMS

The proposed study will include the following major areas:

1. To obtain normative data in a non-clinical setting for blood pressure levels of children and adolescents in Newfoundland and to compare, where possible, this with other data reported in studies done in Canada, the United States and other countries.
2. To identify prospective as well as actual hypertensives from among the study subjects and to acertain hypertension prevalence in

this population. In this study subjects with blood pressure levels ≥ 1 to <2 SDU above the mean of their age and sex group will be considered as prospective hypertensives, and those with blood pressure levels ≥ 2 SDU above the mean for their age and sex group will be considered as hypertensives. (The use of this criteria is explained on page 17.)

3. To determine whether genetic and/or environmental factors might be responsible for the observed blood pressure levels. This will be done by studying the aggregation or clustering of blood pressures within families and by attempting to identify variables which might be associated with blood pressure levels in these subjects. Also of interest would be the identification of those variable(s) which might be predictors or determinants of blood pressure levels.
4. To find out whether there is a "tracking" of systolic and diastolic blood pressures in subjects investigated two years apart.
5. To set up a cohort of subjects which would facilitate longitudinal epidemiological studies of blood pressure levels in children and adolescents.
6. To suggest and incorporate measures to help those who show a tendency towards becoming hypertensives in the future.

CHAPTER 3

LOCALE, STUDY POPULATION AND PROCEDURES

Locale

Two epidemiological studies of blood pressure levels in children and adolescents attending schools in Bay de Verde were organised and carried out in the Spring of 1975 and 1977, respectively. Bay de Verde is a rural Newfoundland community. It is situated on the northern tip of the Avalon Peninsula (Figure 2) and is approximately 183 km by road from St. John's, the capital city. Bay de Verde is a syncline, wedged between two hills of resistant rock. In the valley the land varies from sea level to approximately 61 m above sea level. There are two fairly good natural harbours in the community. The inhabitants refer to these harbours as Fore Side and Back Side. The land is made up of bare, red, brick stone. Because of the sloping of the land to the north, all sources of water flow away from the community. This affects the vegetation which consists mainly of short, stubby grass and the odd stunted growth of juniper on the older trees (65).

All the residents of Bay de Verde are of either English, Scottish or Irish ancestry. Most of these people derive their livelihood from the fishing industry. Some of them are fishermen while others are employed at the fish plant located in the community.

The children living in Bay de Verde attend two schools located in the community. One is an Elementary School which enrols children from Kindergarten to Grade 6. The other is a High School

FIGURE 2

MAP OF NEWFOUNDLAND SHOWING LOCATION OF STUDY SITE

which is attended by those in Grades 7 to 11, inclusive. Both schools are situated alongside the Bay de Verde road, approximately opposite one another. Students attending these schools are transported daily by a school bus. School begins at 9 in the morning and ends at 3 in the afternoon.

Study Population

A total of 100 children and adolescents participated in the first study carried out in 1975. All were white and they ranged from 9 to 18 years of age. There were 56 males and 44 females. These children and adolescents were chosen at random from among those attending the Elementary and High School in Bay de Verde. A total of 320 children and adolescents (92% of the school population) participated in the second survey in 1977. All were white and between 5 and 18 years of age. There were 165 males and 155 females.

The majority of the children and adolescents who did not participate in the 1977 study (28 in number) were absent from school on the day of the survey. No attempt was made to follow-up these absentees. Only one person did not participate in the survey because of parental refusal. As was the case in 1975, letters were sent (see Appendix A) by the Principals of the two schools to parents requesting permission to have their children participate in the survey.

Procedures

a) Introduction

In 1975 blood pressure levels of those who participated in the survey were measured after a questionnaire was administered (see Appendix B). This was followed by measurements of height, weight, and upper arm circumference. However, the data obtained on these three

variables (height, weight and upper arm circumference) are not relevant to this dissertation since this study was only used to study the "tracking" of blood pressure. Therefore, the procedure employed to obtain data on these variables is not reported.

In 1977 the following sequence was followed (see below for details) in both schools for obtaining information. A questionnaire was administered first (Appendix C); this was followed by blood pressure measurements, which in turn, were followed by measurements of height, weight, upper arm circumference, triceps skinfold, subscapular skinfold and an electrocardiogram.

b) Blood Pressure Measurements

Blood pressure measurements were taken by one examiner in 1975 and by another examiner in 1977. On the first occasion (1975), the instrument used to measure blood pressure was an Arteriosonde 1010 automatic blood pressure recorder. On the second occasion (1977) blood pressure was measured with a Physiometrics Automatic Blood Pressure Recorder (Figure 1).

(i) The Arterisonde 1010 Blood Pressure Recorder

The Arterisonde 1010 blood pressure instrument measures blood pressure by ultrasonically detecting arterial wall motion. This motion is then converted to clearly defined signals which are audible through a front panel speaker and interpreted as if they were ordinary Korotkoff sounds. The quality of the sound for determining the blood pressure of a particular patient can be adjusted by a sensitivity switch. In this study (1975), medium sensitivity was used for all measurements. This instrument has a cuff selection switch which electrically matches the instrument to the cuff-transducer assembly;

the latter accommodates variations in arm circumferences.

(ii) Measurements of Blood Pressure with Arteriosonde 1010 Blood Pressure Recorder

Gelisonde, which is an ultrasonic coupling medium, was applied to the face of the transducer which was free of residue, to efficiently couple ultrasound between the transducer and the skin. Before the Cuff-Transducer assembly was placed on the right arm the medial aspect of the upper arm was palpated to locate the brachial artery. The Cuff-Transducer assembly was then placed against the upper arm such that the center of the transducer was over the brachial artery on the medial aspect of the arm. The Cuff-Transducer assembly was then wrapped snugly around the arm, care being taken so as not to change the relative position of the transducer to the brachial artery.

The cuff was inflated to about 30 mmHg above the anticipated systolic blood pressure. The cuff was then deflated at approximately 2 mmHg per second and the sounds from the speaker were correlated with the aneroid guage reading to determine systolic and diastolic (4th phase) blood pressures. The first "pinging" sound was taken as the systolic pressure. The dull (muffling) sound was taken as the diastolic (4th phase) pressure. Blood pressure readings were recorded on a questionnaire (Appendix B).

(iii) Physiometrics Automatic Blood Pressure Recorder

As mentioned above, a Physiometrics Automatic Blood Pressure Recorder was used to take blood pressure measurements in 1977. This instrument was calibrated daily before use with the mercury column of a well-illuminated mercury Baumanometer. The Physiometrics Automatic

Blood Pressure Recorder has a standard rigid cuff which is designed for use on the right upper arm. The cuff contains a microphone which detects Korotkoff sounds and is located under the fabric on the inside of the cuff.

(iv) Measurements of Blood Pressure With Physiometrics Automatic Blood Pressure Recorder

In taking the blood pressure, the right arm was placed in the cuff with the microphone in the cuff located on the distal side (toward the elbow) and over the brachial artery.

When the arm was properly placed, the cuff was closed and the metal hook and the Velcro fastener were secured. The cuff was rapidly inflated until the pen indicated a reading of approximately 30 mmHg higher than the anticipated systolic pressure. The cuff was then deflated at a rate of 2 mmHg per second. The inflation and deflation rates were pre-set on this instrument.

(v) Recording and Interpretation of Blood Pressure Measured With Physiometrics Automatic Blood Pressure Recorder

The blood pressure of each subject was recorded on circular discs graduated in 2 mm. The discs belonging to each subject were labelled with the subject's name and class grade and then stapled together. In interpreting the recording on the discs, the first clear pen stroke which was followed by a series of strokes regularly spaced was taken as the systolic blood pressure. Diastolic pressure (4th phase) was read at the first sharp reduction in pen amplitude following the usual series of pen strokes at the maximum amplitude which was followed by a series of pulses no greater than itself.

(vi) Preparation of Subject Before Measuring Blood Pressure

In 1975 and 1977, blood pressure measurements in both the Elementary and High Schools were taken in spacious classrooms which were set aside for this purpose. The temperature in the rooms was comfortable and was regulated by a thermostat in the room.

The participants were sent into the examining room, four at a time. They were told by their teacher not to run and were encouraged to void before coming to the room. In the room they were told to remove their shoes and any heavy clothing, e.g. sweaters, which they were wearing. They then sat by themselves and were called singly to assist in filling out a questionnaire (see below for more details).

The blood pressure of each subject, in 1975 and 1977, was measured after the subject had been seated quietly for approximately 15 minutes. On both occasions two blood pressure measurements per subject were taken approximately 5 minutes apart from the bare upper right arm. Care was taken to make sure that the arm was resting at heart level once the subject was seated. The procedure of taking the blood pressure and what to expect was explained to each person before the blood pressure was taken. The mean of the two blood pressure readings was used in all analyses.

c) Questionnaire

In 1975 and 1977 each subject was asked to provide information by filling out a questionnaire. A teacher in each of the schools filled out a short questionnaire administered in 1975 (see Appendix B) and a longer one in 1977 (see Appendix C).

In order to authenticate the age of each subject, school records were checked. In addition, each subject was provided with a 13 x 20 cm filing card (see Appendix D) which was taken home for his/her parents to complete and return the next day. In some cases there was more than one member of the same family who took home cards. This allowed for information on these cards to be cross-checked. If the information relating to age, family size, birth order, etc. was conflicting, a phone call was made to the parents to obtain the correct information.

d) Anthropometric Measurements

(i) Height

Height was measured with a steel tape which was affixed to a wall at the top and bottom. In setting up the tape, care was taken to make sure that the bottom of the tape was touching the ground. The tape was graduated in inches as well as centimeters. All readings were taken in centimeters to the nearest 0.5 cm.

The height of each subject was measured once without shoes and with the back square against the wall tape, eyes looking straight ahead. The reading was made with a set square resting on the scalp and against the wall.

(ii) Weight

Weight was measured once with a Counselor bath scale to the nearest kilogram. Subjects were weighed without shoes and in light clothing. The scale was checked for accuracy at the beginning of each day and adjustments were made by turning an adjustable screw when necessary.

(iii) Upper Arm Circumference

Upper arm circumference was measured to the nearest 0.5 cm with a flexible plastic tape graduated in both inches and centimeters. The tape was applied snugly onto the unclothed right arm which was relaxed and pendant with the subject standing. Two measurements were made at a measured mid-point between the tip of the acromion and the tip of the olecranon. The mean of these two measurements was used for analyses.

(iv) Triceps and Subscapular Skinfolds

Skinfold measurements were made on the right side of the subject and recorded to the nearest 0.5 millimeter. Measurements were taken twice and the mean of the two measurements used in the analyses. If the subject complained or showed signs of pain, the measurements was discontinued and another measurement was made. All measurements were made with a Lange Skinfold Caliper. This instrument is designed to exert a constant pressure of 10 g/mm^2 throughout the range of jaw openings. The accuracy of the caliper was tested daily by checking it against a metallic standard of known width.

-Triceps Skinfold

The triceps skinfold was measured between the acromiun and the tip of the elbow over the triceps muscle of the right arm, with the subject standing. The measured skinfold was grasped between the thumb and the index finger and lifted parallel to the long axis of the arm.

-Subscapular Skinfold

The subscapular skinfold was measured just below the inferior angle of the right scapula with the subject standing in a relaxed

position. The skinfold was grasped between the thumb and the index finger. This fold runs at an angle of about 45° downwards from the spine.

All blood pressure measurements and anthropometric measurements were made by the author.

e) Electrocardiograms

Six-lead electrocardiograms were recorded on a direct writing single channel instrument (Hewlett Packard Model 1500) at a paper speed of 25 mm per second. The conventional standardisation was used, that is, 1 mm amplitude for each 0.1 millivolt. This means that the sensitivity control of the recorder was set to give a 10 mm deflection for 1 millivolt of potential. The standard limb leads - I, II, and III, as well as unipolar limb leads AVR, AVL and AVF were recorded after the subject had been lying for approximately 5 minutes. Each recorded lead was coded and the name and class grade of the subject placed on the electrocardiogram for subsequent identification.

Care was taken to make sure that the equipment was adequately grounded and the electrodes were correctly placed. Paste was liberally applied to the electrodes which were than placed firmly in contact with the skin. A recording of 4 seconds duration or more was made with a stable baseline for each lead.

All electrocardiograms were done by a nursing assistant, who was trained in the taking of electrocardiograms.

CHAPTER 4

METHODS OF DATA ANALYSIS

Introduction

All data were transferred to punch cards and analysis was carried out by IBM 370 computer at a branch of the Newfoundland and Labrador Computing Services, located on the campus of Memorial University of Newfoundland. Two tailed tests of statistical significance have been used throughout and the level for statistical significance was chosen as $p \leq 0.05$.

In cases where two measurements of a variable were made per subject, the mean of the two measurements was used in analysing the data. Variables which were measured twice in each subject include blood pressures in 1975 and 1977, upper arm circumference, triceps skinfold thickness, and subscapular skinfold thickness in 1977.

a) Grouping of Subjects According to Age

The data were analysed for two year age intervals because the number of subjects in one year age groups was rather small. For the 1975 data on blood pressure, the age groups were 9 - 10, 11 - 12, 13 - 14, 15 - 16, and 17 - 18. The data collected in 1977 were analysed for the following age groups: 5 - 6, 7 - 8, 9 - 10, 11 - 12, 13 - 14, 15 - 16, and 17 - 18, except in the case of multiple linear regression analysis where there were two age groups, 5 - 12 and 13 - 18. The reasons for this grouping are given in the section entitled "Multiple Linear Regression Analysis" below.

b) Age and Sex Adjusted Score in Standard Deviation Units

In order to adjust for age and sex, blood pressures were expressed in standard deviation units (SDU). The SDU is equal to the observed recorded blood pressure for an individual minus the mean blood pressure for the subject's two year age and sex group, divided by the standard deviation of the blood pressure in that age and sex group.

This method indicates that those individuals whose standard deviation units are positive have blood pressure levels higher than the mean for their own age and sex group, and those with negative values have blood pressure levels lower than the mean for their own age and sex group.

SDU's were also calculated for height, weight, and Quetelet Index (wt/ht^2) because these variables are known to be affected by age and sex.

The standardisation of raw blood pressure values, by converting to SDU's, also allows for comparison of blood pressure levels which were obtained with different instruments, for example, the Arteriosonde 1010 and Physiometrics recorder, and by different examiners. The errors due to lack of precision in the taking of blood pressure measurements with different instruments and by different examiners would be systematic errors and so by converting blood pressure values to SDU's, these errors are likely to be eliminated.

c) Quetelet Index (wt/ht^2)

The Quetelet Index is an index of body mass (66) and was computed to provide a measure of weight corrected for height. In this computation, weight was in kilograms and height in centimeters

multiplied by 100.

d) Family Size

The size of the nuclear family was used in this analysis. The nuclear family consisted of the father, mother, and their children (Item No. 12 on questionnaire, Appendix C). The size of the nuclear family referred only to living members.

e) Birth Order

Birth order of each subject was recorded in terms of first born, second born, etc. In determining birth order, deceased individual(s) were taken into account.

f) Age

Age was recorded in years of the subject as of June 30, 1975, in the 1975 survey, and as of June 30, 1977, in the 1977 survey.

g) Resting Heart Rate (Beats Per Minute)

Each electrocardiogram was checked first for regularity of rhythm and other abnormalities. None was found. Resting heart rate was then calculated from lead II by determining the number of fifths of a second between consecutive beats. The R - R complex was chosen and the number of fifths elapsing before the same complex recurs was counted. Since there are only 300 fifths of a second in a minute, the heart rate (number of beats per minute) was determined by the number of fifths counted. For example, 1/5 second between consecutive beats would give a rate of 300 beats per minute, 3/5 would give a rate of 100 beats per minute. The number of fifths was obtained with the aid of a caliper. This enabled measurements to be moved away from the EKG graph to a more convenient place on the graph paper, thereby

facilitating the calculation of the heart rate.

h) Amplitude of P Wave (mm)

The amplitude of P wave was measured from lead II, by counting the number of small squares from the EKG baseline to the tip of the wave. This means that the baseline was considered the zero point for measuring the height. Each of the small squares in the vertical measurements is equal to a distance of one millimeter (1 mm). One large square is equal to 5 mm. Distances above the baseline were considered positive.

j) Amplitude of R Wave (mm)

The amplitude of the R wave was determined from lead II and was measured using the same procedure as that for the amplitude of the P wave.

k) Descriptive Statistics - Means and Standard Deviations

Means and standard deviations were calculated for males and females based on two year age intervals for the following variables: systolic blood pressure (Table 8); diastolic (4th phase) blood pressure (Table 9); height, weight, triceps skinfold thickness, subscapular skinfold thickness, upper arm circumference (Tables 10, 11) resting heart rate, amplitude of P wave in lead II, and amplitude of R wave in lead II (Tables 16, 17)

m) Inferential Statistics

(i) Correlation Coefficients

Pearson correlation coefficients were calculated in order to ascertain the strength of association between blood pressure [systolic and diastolic (4th phase)] and the other variables (Tables 12, 13, 14, 15, 18, 19, 20, 21)

These correlation coefficients also provide a means for comparing the strength of the relationship between one pair of variables and another pair. Pearson correlation was used because the variables being correlated are continuous variables.

Spearman rank order correlations were carried out to obtain correlations between blood pressure [systolic and diastolic (4th phase)] and family size, and birth order (Tables 20,21). Spearman rank order correlations were used because family size and birth order are rank order variables.

(ii) Meaning of Correlation Coefficients

Values of correlation coefficients can never be greater than 1.0 nor less than -1.0. A positive correlation implies that for an increase in the value of one of the variables, the other variable also increases in value. A negative correlation indicates that an increase in value of one of the variables is accompanied by a decrease in value of the other variable. A correlation of zero denotes no association between the magnitudes of the two variables; that is, a change in magnitude of one does not imply a change in magnitude of the other.

Although in correlation analysis the linear relationship between two variables is being considered, neither is assumed to be functionally dependent upon the other.

n) Multiple Linear Regression Analysis

Multiple linear regression analysis was carried out with blood pressure (systolic and diastolic - 4th phase) as the dependent variable and the eleven variables used in the correlation analysis as independent variables. These 11 variables were height, weight,

Quetelet Index, triceps skinfold thickness, subscapular skinfold thickness, upper arm circumference, heart rate, amplitude of P wave in lead II, amplitude of R wave in lead II, family size and birth order.

Multiple linear regression analysis was undertaken in order to find out which of the independent variables were determinants of blood pressure levels. The general population model for a multiple regression equation is as follows:

$$Y_i = a + b_1x_{1i} + b_2x_{2i} = b_3x_{3i} \ldots + b_mx_{mi}$$

where Y_i is the dependent variable, in this case systolic and diastolic (4th phase) blood pressures respectively.

a - the value of the dependent variable (blood pressure) when all the independent variables are zero;

b_1, b_2, b_3 .... b_m - partial regression coefficients;

x_{1i}, x_{2i}, x_{3i} .... x_{mi} - the independent variables.

Each partial regression coefficient expresses how much the dependent variable (blood pressure) would change for a unit change in one of the independent variables if all the other independent variables were held constant. They are called partial regression coefficients because each expresses only part of the independence of the dependence relationship.

In this analysis, x_{1i} = height, x_{2i} = weight, x_{3i} = Quetelet Index, x_{4i} = triceps skinfold thickness, x_{5i} = subscapular skinfold thickness, x_{6i} = upper arm circumference, x_{7i} = heart rate, x_{8i} = amplitude of P wave in lead II, x_{9i} = amplitude of R wave in

in lead II, x_{10i} = family size, and x_{11i} = birth order.

The multiple linear regression analysis was carried out with the dependent variables, systolic and diastolic (4th phase) blood pressure, in SDU's (Tables 27, 28, 29, 30). The independent variables (height, weight, and Quetelet Index) were also converted to SDU's using two year age groups. By converting data on these variables to SDU's, the known effects of age and sex on these variables were eliminated.

Multiple linear regression analysis was done for two groups (Tables 27, 28, 29, 30); one group consisting of children 5 - 12 years of age and the other consisting of adolescents 13 - 18 years of age. It was necessary to make such a division because of the restriction in carrying out multiple linear regression analysis. The restriction is that the number of values of the dependent variable must exceed the number of independent variables in the analysis by two, that is, m + 2 values of the dependent variable are required to perform a multiple regression analysis (67). Therefore, since in this analysis there are 11 independent variables, a minimum of 13 subjects in each age category would be required. This requirement could not be fulfilled for males in the 17 - 18 year age group, where there were only 11 subjects. Thus, there was need for a larger group. A decision was taken, therefore, to divide the group into children 5 - 12 years of age, and adolescents 13 - 18 years of age, since it was hypothesised that the determinants of blood pressure levels might be different for children and adolescents.

It was further hypothesised that for each group blood pressure was functionally dependent on each of the independent

variables. This hypothesis was tested by analysis of variance for each group by testing the hypothesis of no dependence of blood pressure on the independent variables, x_i, i.e. $b_1 = b_2 = \ldots . b_m = 0$ (versus H_a: all m population partial regression coefficients were not equal to zero).

The results of these tests were highly significant (see Appendix E).

o) Analysis of Variance

The technique of analysis of variance (ANOVA) was used (1977 data) to study familial aggregation of systolic and diastolic (4th phase) blood pressures among and within 85 families consisting of 259 subjects ranging from 5 - 18 years of age. Each family in the analysis consisted of two or more subjects.

ANOVA compares the variation among the means of family blood pressures to the total variation within all the families. The variability of blood pressure scores among and within families is tested by means of the F statistic.

p) Scattergram and Simple Linear Regression

On examining the data obtained in 1977, it was found that there were 68 subjects who had their blood pressures recorded in 1975. The "tracking" of the blood pressure of these 68 subjects was investigated by plotting a scattergram with blood pressure scores in SDU for 1977 as the dependent variable and blood pressure scores in SDU for 1975 as the independent variable.

The statistics obtained with the scattergram are those normally associated with simple linear regression, this is, slope of the regression line, standard error of estimate and level of

statistical significance.

Regression lines were drawn for follow-up systolic SDU in 1977 versus initial systolic SDU in 1975 (Figure 4) and follow-up diastolic (4th phase) SDU in 1977 versus initial diastolic (4th phase) SDU in 1975 (Figure 6).

CHAPTER 5

RESULTS

INTRODUCTION

Results will be reported in the following four sections:

1. Prevalence of Hypertension;
2. Familial Aggregation of Blood Pressure;
3. "Tracking" of Blood Pressure;
4. Factors Associated with Blood Pressure Levels in Children and Adolescents 5-18 Years of Age.

SECTION 1

Prevalence of Hypertension

Standard Deviation Unit scores for systolic and diastolic (4th phase) blood pressure were calculated for two year age groups as described in the Chapter Methods of Data Analysis (Page 52). The frequency of blood pressure scores in SDU was obtained for scores falling into one of the following six categories: <-2, ≥-2 to <-1, ≥-1 to <0, ≥0 to <1, ≥1 to <2 and ≥2.

Blood pressure scores which fell into the SDU category of ≥1 to <2 were considered as "high normal". Blood pressure scores in the SDU category ≥2 were considered as hypertensive (see page 17 for an explanation for the use of such criteria).

a) Systolic Blood Pressure

As Table 4 indicates, for systolic blood pressure there were 4 persons (1.2%) with SDU scores of <-2, 40 (12.5%) with SDU scores ≥-2 to <-1, 122 (38.1%) with SDU scores ≥-1 to <0, 103 (32.3%)

with SDU scores ≥ 0 to <1, 46 (14.4%) with SDU scores ≥ 1 to <2 and 5 (1.6%) with SDU scores ≥ 2.

b) Diastolic Blood Pressure

The distribution of SDU scores for diastolic (4th phase) blood pressure is shown in Table 4. There were seven persons (2.2%) with SDU scores <-2, 48 (15.0%) with SDU scores ≥ -2 to <-1, 99 (30.9%) with SDU scores ≤ -1 to <0, 112 (35.0%) with SDU scores ≥ 0 to <1, 49 (15.3%) with SDU scores ≥ 1 to <2 and 5 (1.6%) with SDU scores ≥ 2.

SECTION 2

Familial Aggregation of Blood Pressure

a) Familial Aggregation of Systolic Blood Pressure

The results of analysis of variance (Table 5) show that there was a significant clustering or aggregation of systolic blood pressure within families for subjects aged 5 - 18 years. The F value obtained was 1.51 ($p < 0.01$).

b) Familial Aggregation of Diastolic (4th Phase) Blood Pressure

As indicated in Table 5, there was a significant clustering or aggregation of diastolic (4th phase) blood pressure within families for subjects 5 - 18 years. The F value obtained was 1.51 ($p < 0.01$).

SECTION 3

"Tracking" of Blood Pressure

a) "Tracking" of Systolic Blood Pressure

The distribution patterns in 1977 of follow-up blood pressure scores of 68 subjects in relation to their initial scores in 1975 are shown in Tables 6 and 7 and depicted in Figures 3 and 5 in

TABLE 4

DISTRIBUTION OF SYSTOLIC AND DIASTOLIC (4TH PHASE)

BLOOD PRESSURE SCORES IN SDU OF SUBJECTS AGED 5-18 YEARS

SYSTOLIC SDU SCORES	NO. OF SUBJECTS	PERCENT (%)
<-2	4	1.2
≥-2 to <-1	40	12.5
≥-1 to < 0	122	38.1
≥ 0 to < 1	103	32.2
≥ 1 to < 2	46	14.4
≥ 2	5	1.6
TOTALS	320	100.0

DIASTOLIC SDU SCORES	NO. OF SUBJECTS	PERCENT (%)
<-2	7	2.2
≥-2 to <-1	48	15.0
≥-1 to < 0	99	30.9
≥ 0 to < 1	112	35.0
≥ 1 to < 2	49	15.3
≥ 2	5	1.6
TOTALS	320	100.0

TABLE 5

ANALYSIS OF VARIANCE OF SYSTOLIC AND DIASTOLIC (4TH PHASE)

BLOOD PRESSURE SCORES IN SDU FOR ENTIRE GROUP, 5-18 YEARS OF AGE

SOURCE OF VARIATION	SYSTOLIC SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F SCORE	p
Among families	92.04	84	1.10	1.51	0.01
Within families	126.36	174	0.73		

SOURCE OF VARIATION	DIASTOLIC SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F SCORE	p
Among families	89.48	84	1.07	1.51	0.01
Within families	122.71	174	0.71		

the form of a bar graph. Of seven subjects with initial systolic scores greater than 1.0 SDU above the mean, 5 (71%) had positive SDU scores at follow-up. Of nine subjects with initial systolic scores, less than 1.0 SDU below the mean, 7 (78%) had negative follow-up scores (Table 6).

Simple linear regression statistics of the follow-up systolic blood pressure on the initial systolic blood pressure is shown in Figure 4. The regression coefficient was 0.53 ($p < 0.00002$).

b) "Tracking" of Diastolic (4th Phase) Blood Pressure

In the case of diastolic (4th phase) blood pressure, of eight subjects with initial scores greater than 1.0 SDU above the mean, 7 (88%) had positive scores at follow-up. Of the 13 with initial scores less than 1.0 SDU below the mean, 9 (69%) had negative scores at follow-up (Table 7).

Simple linear regression statistics of the follow-up diastolic (4th phase) blood pressure on the initial diastolic (4th phase) blood pressure is shown in Figure 6. The regression coefficient was 0.19 ($p < 0.05$).

These results indicate that there was a strong significant positive relation of follow-up to initial systolic blood pressures. Diastolic blood pressures show a small, but significant positive relation of follow-up to initial blood pressure values. Thus, the ranking or "tracking" effect was significantly stable.

SECTION 4

Factors Associated With Blood Pressure Levels in Children and Adolescents 5 - 18 Years of Age

TABLE 6

NUMBER OF SUBJECTS IN VARIOUS SYSTOLIC SDU CATEGORIES AT THE INITIAL STUDY (1975), AND THE DISTRIBUTION OF THESE SUBJECTS AT THE FOLLOW-UP STUDY (1977)

INITIAL SYSTOLIC SDU		FOLLOW-UP SYSTOLIC SDU							
		-1		-1 to 0		0 to 1		1	
	No.	No.	%	No.	%	No.	%	No.	%
<-1	9	4	44	3	33	1	11	1	11
-1 to <0	21	4	19	10	48	7	33	0	0
0 to 1	31	1	3	8	26	12	39	10	32
>1	7	0	0	2	29	2	29	3	42

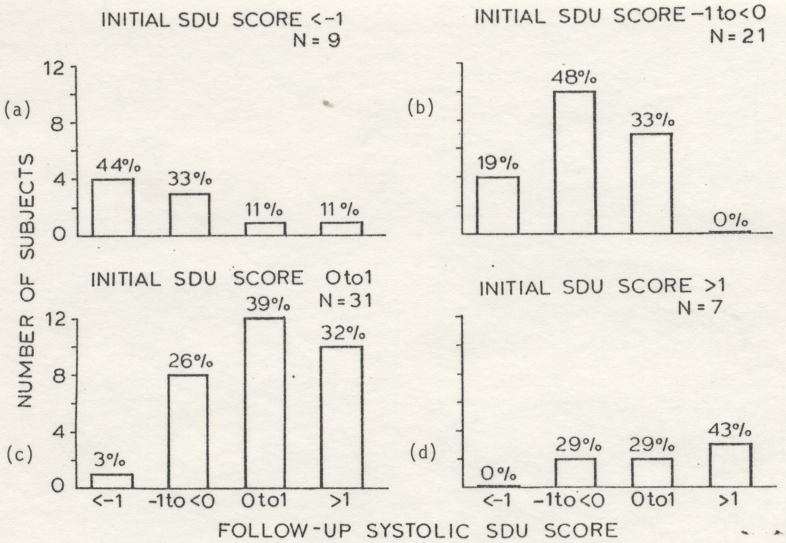

FIGURE 3

DISTRIBUTION OF FOLLOW-UP SYSTOLIC BLOOD PRESSURE SCORES IN SDU: (a) FOR INITIAL SCORE < -1; (b) FOR INITIAL SCORE -1 to < 0; (c) FOR INITIAL SCORE 0 to 1; (d) FOR INITIAL SCORE > 1

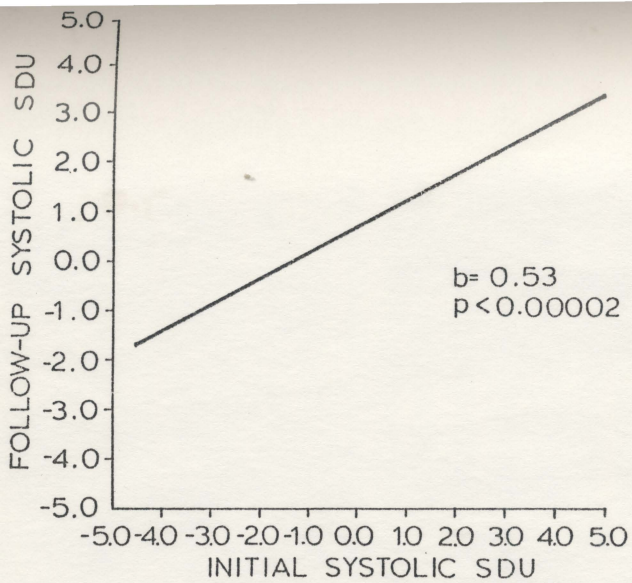

FIGURE 4

FOLLOW-UP SYSTOLIC BLOOD PRESSURE IN SDU (1977)

ON INITIAL SYSTOLIC BLOOD PRESSURE IN SDU (1975)

TABLE 7

NUMBER OF SUBJECTS IN VARIOUS DIASTOLIC SDU CATEGORIES AT THE INITIAL STUDY (1975), AND THE DISTRIBUTION OF THESE SUBJECTS AT THE FOLLOW-UP STUDY (1977)

INITIAL DIASTOLIC SDU		FOLLOW-UP DIASTOLIC SDU							
		-1		-1 to 0		0 to 1		1	
	No.	No.	%	No.	%	No.	%	No.	%
<-1	13	1	8	8	62	2	15	2	15
-1 to <0	17	2	12	6	35	8	47	1	6
0 to 1	30	7	23	4	13	13	43	6	20
>1	8	0	0	1	13	4	50	3	38

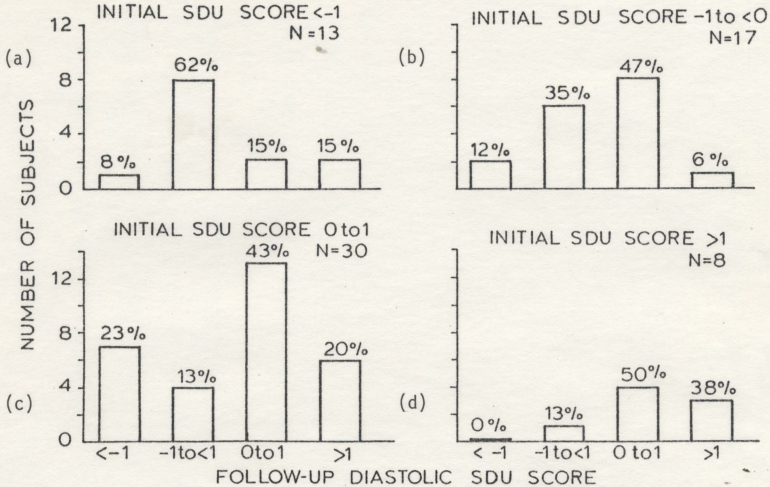

FIGURE 5

DISTRIBUTION OF FOLLOW-UP DIASTOLIC (4TH PHASE) BLOOD PRESSURE SCORES IN SDU: (a) FOR INITIAL SCORE <-1; (b) FOR INITIAL SCORE -1 to <0; (c) FOR INITIAL SCORE 0 TO 1; (d) FOR INITIAL SCORE >1

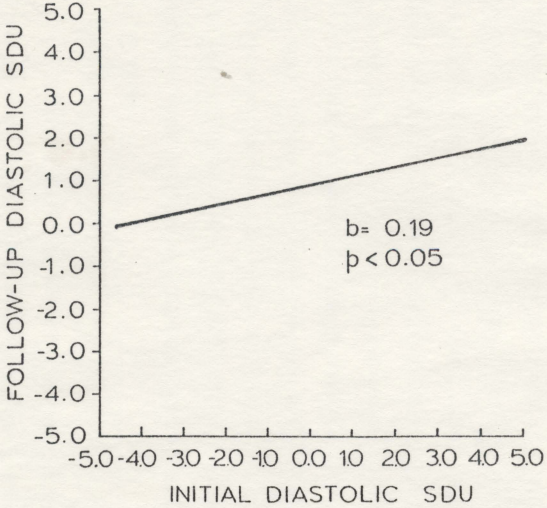

FIGURE 6

FOLLOW-UP DIASTOLIC (4TH PHASE) BLOOD PRESSURE IN SDU

ON INITIAL DIASTOLIC (4TH PHASE) BLOOD PRESSURE IN SDU

a) Systolic and Diastolic (4th phase) Blood Pressure

(i) Systolic Blood Pressure

In males, systolic blood pressure ranged from 101.3 mmHg for the 5 - 6 year age group to 124.8 mm Hg for the 17 - 18 year age group. For females, the range was from 96.6 mmHg for the 5-6 year age group to 118.4 mmHg for the 17-18 year age group.

Mean systolic blood pressures were higher for males than for females in each corresponding age group, the only exception being the 9 - 10 year age group where females had a slightly higher mean systolic blood pressure - 104.8 mmHg versus 103.6 mmHg. The greatest differences in mean systolic blood pressure between the sexes was in the 15 - 16 and 17 - 18 year age groups (Table 8).

Figure 7 shows a graph of the mean systolic blood pressure versus age. It can be seen that the mean systolic blood pressure increases with age for both males and females, except in the case of 9 - 10 year old males where there was a slight decrease. The increase of systolic blood pressure with age was more consistent for females than for males.

(ii) Diastolic (4th Phase) Blood Pressure

Table 9 shows the mean and standard deviation of diastolic (4th phase) blood pressure by sex and two year age groups for the 320 participants 5 - 18 years of age. The mean diastolic blood pressure in males ranged from 57.0 mmHg in the 5 - 6 year age group to 73.7 mmHg in the 17 - 18 year age group. In the females the range in mean diastolic blood pressure was 60.7 mmHg for 5 - 6 year age group to 69.3 mmHg for 17 - 18 year age group. Males in the 7 - 8,

TABLE 8

MEAN AND STANDARD DEVIATION (S.D.) OF SYSTOLIC BLOOD PRESSURE IN mmHg BY SEX AND TWO-YEAR AGE GROUPS

MALES

AGE (years)	MEAN	S.D.	NO.
5-6	101.3	10.3	14
7-8	104.3	8.9	28
9-10	103.6	7.9	21
11-12	112.1	10.4	35
13-14	114.5	11.5	34
15-16	123.0	15.0	22
17-18	124.8	11.1	11

FEMALES

AGE (years)	MEAN	S.D.	NO.
5-6	96.6	9.1	14
7-8	103.3	7.6	20
9-10	104.8	5.8	22
11-12	108.6	10.9	29
13-14	113.3	9.8	35
15-16	117.4	11.0	21
17-18	118.4	11.5	14

TABLE 9

MEAN AND STANDARD DEVIATION (S.D.) OF DIASTOLIC (4TH PHASE)

BLOOD PRESSURE IN mmHg BY SEX AND TWO-YEAR AGE GROUPS

MALES

AGE (years)	MEAN	S.D.	NO.
5-6	57.0	8.6	14
7-8	63.9	6.8	28
9-10	67.6	6.8	21
11-12	67.9	8.9	35
13-14	65.4	6.6	34
15-16	67.6	6.5	22
17-18	73.7	6.0	11

FEMALES

AGE (years)	MEAN	S.D.	NO.
5-6	60.7	8.8	14
7-8	63.3	8.5	20
9-10	65.4	8.2	22
11-12	66.7	10.0	29
13-14	68.5	6.3	35
15-16	72.1	11.2	21
17-18	69.3	4.8	14

9 - 10, 11 - 12, and 17 - 18 age groups had higher mean diastolic (4th phase) blood pressure than females of the corresponding age groups. In the 5 - 6, 13 - 14, and 15 - 16 age groups, females had higher mean diastolic (4th phase) blood pressure than males.

Figure 7 shows that there was a consistent increase of mean diastolic blood pressure with age for females. In the case of males the increase of mean diastolic blood pressure (4th phase) with age was less consistent.

b) Anthropometric Characteristics

(i) Height

As indicated in Tables 10 and 11, males were taller than females in all age groups. The height of males ranged from 115.5 cm for the 5 - 6 year age groups to 175.3 cm for the 17 - 18 year age group. For females, the range was 113.4 cm for those in the 5 - 6 year age group to 161.3 cm for the 17 - 18 year age group. The smallest difference in height between the sexes was in the 9 - 10 year ag group where there was a difference of only 0.2 cm. The greatest differences in height were in the 15 - 16 and 17 - 18 year age groups where males were much taller than females.

(ii) Correlation Between Height and Blood Pressure

-Correlation between height and systolic blood pressure

The coefficients obtained from correlation analysis between height and systolic blood pressure (Tables 12 and 13) were positive for all age groups, except the 17 - 18 year age groups for both sexes. For males the strongest correlation (0.14) between height and systolic blood pressure was in the 5 - 6 year age group.

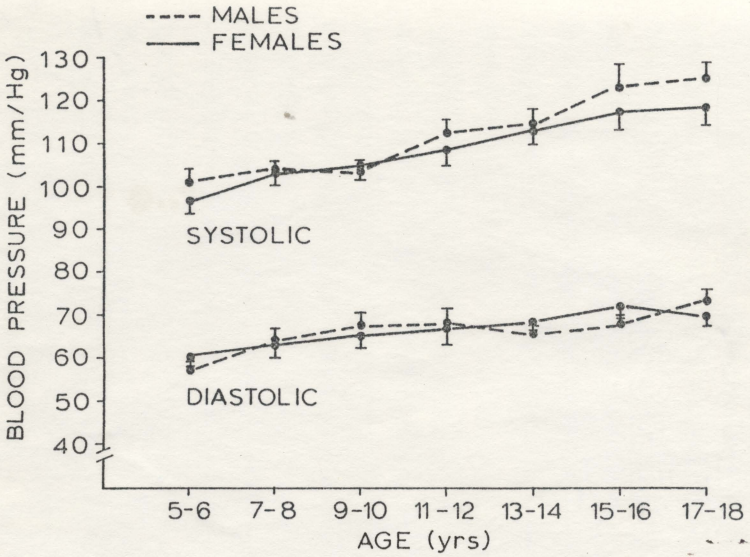

FIGURE 7

MEAN BLOOD PRESSURE (mm/Hg), MEASURED BY PHYSIOMETRICS AUTOMATIC BLOOD PRESSURE RECORDER, OF 320 CHILDREN AND ADOLESCENTS BY AGE (YEARS) AND SEX

The strongest correlation obtained for females was 0.58. This was in the 9 - 10 year age group.

-Correlation between height and diastolic (4th phase) blood pressure

Correlations were positive for height and diastolic (4th phase) blood pressure in all age groups for both sexes. For males the strongest correlation was 0.64 in the 5 - 6 year age group, and the weakest correlation was 0.06 in the 13 - 14 year age group. For females, the strongest correlation was 0.72 in the 5 - 6 year age group, and the weakest correlation was 0.01 in the 13 - 14 year age group (Tables 14 and 15).

(iii) Weight

Tables 10 and 11 show that in all age groups, except 13 - 14, males were heavier than females. The range in weight for males was 23.6 kg, for those in the 5 - 6 year age group, to 68.6 kg, for those in the 17 - 18 year age group. For females the range in weight was 20.0 kg for those in the 5 - 6 year age group to 60.1 kg for those in the 17 - 18 year age group. The smallest difference in weight between the sexes (0.7 kg) was in the 7 - 8 year age group. The greatest difference in weight was in the 15 - 16 and 17 - 18 year age group where males were much heavier than females.

(iv) Correlation Between Weight and Blood Pressure

-Correlation between weight and systolic blood pressure

Tables 12 and 13 show the correlation coefficients for weight and systolic blood pressure for males and females of the various age groups. For males the strongest correlation (0.41) was obtained in the 13 - 14 year age group. A negative correlation (-0.10)

was obtained for those males in the 17 - 18 year age group. Among the female age groups, the strongest correlation (0.42) was in the 13 - 14 year age group. A negative correlation of 0.03 was obtained for those in the 5 - 6 year age group.

-Correlation between weight and diastolic (4th phase) blood pressure

The correlation analysis for weight and diastolic (4th phase) blood pressure (Tables 14 and 15) shows that the strongest correlation (0.49) for males was in the 5 - 6 year age group. A negative correlation of 0.03 was obtained for males in the 11 - 12 year age group. In the case of females those in the 17 - 18 year age group had the strongest correlation (0.52) between weight and diastolic (4th phase) blood pressure. Females in the 9 - 10 year age group had the weakest correlation of 0.12.

(v) Correlation Between Quetelet Index (wt/ht^2) and Blood Pressure

-Correlation between Quetelet Index (wt/ht^2) and systolic blood pressure

Correlations between the Quetelet Index and systolic blood pressure for males show (Tables 13 and 14) that those in the 13 - 14 year age group have the strongest correlation - a value of 0.40. A negative correlation was obtained for males in the 5 - 6 year age group. The correlation coefficients were stronger among the 13 - 14, 15 - 16 and 17 - 18 year age groups than among the 5 - 6, 7 - 8, 9 - 10 and 11 - 12 year age groups.

Females in the 17 - 18 year age group had the strongest correlation (0.39) for Quetelet Index and systolic blood pressure. A weak negative correlation of 0.08 was obtained for those in the 5 - 6

year age group.

-Correlation between Quetelet Index (wt/ht^2) and diastolic (4th phase) blood pressure

For males, the correlation coefficient for Quetelet Index and diastolic (4th phase) blood pressure (Tables 15 and 16) was strongest (0.17) in the 5 - 6 year age group. The weakest correlations (0.05) were observed in the 7 - 8 and 15 - 16 year age groups. The weakest correlations (0.05) were observed in the 7-8 and 15 - 16 year age groups. The correlations , although small, were positive in all the other age groups.

For females the correlations between Quetelet Index and diastolic (4th phase) blood pressure were positive for all age groups, except the 5 - 6 year age group which showed a low negative correlation of 0.08. The strongest correlation was 0.51 in the 17 - 18 year age group.

(vi) Triceps Skinfold Thickness

Triceps skinfold thickness, as indicated in Tables 10 and 11, varied among the different age groups. The maximum value for males was 16.7 mm for those in the 11 - 12 year age group. The minimum value was 9.5 mm for males in the 7 - 8 year age group. Among females the maximum triceps skinfold thickness was 20.1 mm in the 17 - 18 year age group. The minimum value was 10.1 in the 5 - 6 female age group.

Females in all age groups, except 5 - 6 and 9 - 10, had higher mean triceps skinfold thickness than males (Tables 10 and 11).

(vii) Correlation Between Triceps Skinfold Thickness and Blood Pressure

-Correlation between triceps skinfold thickness and systolic blood pressure

In Tables 12 and 13 the strongest correlation among the male groups between triceps skinfold thickness and systolic blood pressure was 0.36, and this was in the 15 - 16 year age group. Positive correlations were also obtained for the 7 - 8, 9 - 10, 13 - 14 and 17 - 18 year age groups. Negative correlations were observed for the 5 - 6 and 11 - 12 year age groups.

Among the female age groups the strongest correlation between triceps skinfold thickness and systolic blood pressure was 0.29. This was in the 9 - 10 age group. Positive correlations were also observed for the 15 - 16 and 17 - 18 age groups. Negative correlaations were obtained for the 5 - 6, 7 - 8, 11 - 12 and 13 - 14 age groups (Table 13).

-Correlation between triceps skinfold thickness and diastolic (4th phase) blood pressure

For diastolic (4th phase) blood pressure and triceps skinfold thickness the strongest correlation among the male groups was 0.49. This correlation was observed for the 17 - 18 year age group. The weakest correlation was 0.02 obtained for 9 - 10 year age group. All other male age groups showed positive correlations (Table 12).

Among the female age groups, the strongest correlation between diastolic (4th phase) blood pressure and triceps skinfold thickness was 0.32. This was obtained for the 17 - 18 year age group. All other correlations in this sex group were positive (Table 13).

(viii) Subscapular Skinfold Thickness

As shown in Tables 10 and 11, subscapular skinfold thickness was highest for males in the 17 - 18 year age group and lowest for those males in the 5 - 6 year age group. The minimum value for females was 6.1 mm for those in the 5 - 6 year age group and the maximum was 19.3 mm for those in the 17 - 18 year age group. The results indicate no increase of subscapular skinfold thickness with age for either sex.

(ix) Correlation Between Subscapular Skinfold Thickness and Blood Pressure

-Correlation between subscapular skinfold thickness and systolic blood pressure

The strongest correlation among the male age groups between systolic blood pressure and subscapular skinfold thickness was 0.55, observed in the 17 - 18 year age group. With the exception of the 5 - 6 and 11 - 12 year age groups where the correlations were negative, all other correlations were positive (Table 12).

The strongest correlation for the female groups was 0.27 in the 17 - 18 year age group. A negative correlation was obtained for the 5 - 6 year age group. Positive correlations were obtained for all the other age groups (Table 13).

-Correlation between subscapular skinfold thickness and diastolic (4th phase) blood pressure

The correlation between diastolic (4th phase) blood pressure and subscapular skinfold thickness showed that among the male age groups, the 17 - 18 year age group had the strongest correlation (0.64). Negative correlations were obtained for the 9 - 10 and 11 - 12 year age groups. All other age groups showed positive correlations (Table 14).

(x) Upper Arm Circumference

Tables 10 and 11 show that except for males in the 5 - 6 and 7 - 8 year age groups, upper arm circumference increased with age for both sexes. The minimum value for males was 19.1 cm for those in the 5 - 6 and 7 - 8 year age groups. The maximum value for males was 27.2 cm for those in the 17 - 18 year age group.

The minimum value for upper arm circumference for females was 17.4 cm for those in the 5 - 6 year age group. The maximum value for females was 25.4 cm for those in the 17 - 18 year age group.

(xi) Correlation Between Upper Arm Circumference and Blood Pressure

-Correlation between upper arm circumference and systolic blood pressure

As indicated in Table 12, for males the strongest correlation between systolic blood pressure and upper arm circumference was 0.41 in the 13 - 14 year age group. There was no correlation in the 9 - 10 year age group. The weakest correlation (0.01) was in the 5 - 6 year age group. A negative correlation was obtained for the 11 - 12 year age group. Positive correlations were obtained for all other age groups.

Among females, the strongest correlation between systolic blood pressure and upper arm circumference was 0.46, obtained for the 17 - 18 year age group. The weakest correlation (0.03) was in the 13 - 14 year age group. A negative correlation was obtained for those in the 5 - 6 female age group (Table 13).

TABLE 10

ANTHROPOMETRIC CHARACTERISTICS OF MALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
No. of subjects	14	28	21	35	34	22	11
Height (cm)							
Mean	115.5	125.0	136.5	147.3	158.9	174.0	175.3
S.D.	5.5	7.3	9.0	7.2	9.7	5.7	8.1
Weight (kg)							
Mean	23.6	26.6	34.6	39.0	48.1	63.4	68.6
S.D.	3.8	5.2	11.2	6.7	11.1	12.0	12.8
Triceps Skinfold (mm)							
Mean	11.1	9.5	16.2	16.7	13.1	12.6	15.1
S.D.	4.5	3.5	10.3	6.5	5.6	5.6	8.0
Subscapular Skinfold (mm)							
Mean	7.1	7.4	12.2	10.1	12.0	12.1	14.1
S.D.	4.5	4.2	10.3	8.0	6.7	5.9	4.7
Upper Arm Circumference (cm)							
Mean	19.1	19.4	21.2	21.8	23.7	26.6	27.2
S.D.	1.5	2.1	3.6	2.1	3.2	2.8	2.2

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TABLE 11

ANTHROPOMETRIC CHARACTERISTICS OF FEMALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
No. of subjects	14	20	22	29	35	21	14
Height (cm)							
Mean	113.5	123.9	136.3	145.1	155.8	160.8	161.3
S.D.	5.2	5.8	8.0	7.9	7.5	6.2	4.4
Weight (kg)							
Mean	20.0	25.9	32.7	38.2	49.4	55.8	60.1
S.D.	2.6	5.3	8.8	8.7	9.8	10.9	10.4
Triceps Skinfold (mm)							
Mean	10.1	12.0	16.1	15.6	19.2	16.9	20.1
S.D.	4.4	5.1	8.3	6.2	7.1	5.9	7.7
Subscapular Skinfold (mm)							
Mean	6.1	8.4	13.1	9.5	16.9	16.1	19.3
S.D.	3.4	8.1	12.9	5.5	6.7	5.9	8.7
Upper Arm Circumference (cm)							
Mean	17.4	19.2	20.7	21.2	23.7	24.8	25.4
S.D.	1.7	2.3	3.0	2.6	2.6	2.9	3.0

TABLE 12

CORRELATION BETWEEN SYSTOLIC BLOOD PRESSURE AND SEVERAL VARIABLES

IN MALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
No. of cases	14	28	21	35	34	22	11
Height	0.41	0.17	0.10	0.25	0.33	0.24	-0105
Weight	0.04	0.14	0.12	0.12	0.41	0.21	-0.10
Quetelet Index	-0.24	0.05	0.02	0.03	0.40	0.16	0.13
Triceps Skinfold	-0.26	-.19	0.02	-0.02	0.13	0.36	0.18
Subscapular Skinfold	-0.37	0.19	0.09	-0.16	0.36	0.11	0.55
Upper Arm Circumference	0.01	0.15	0.00	-0.16	0.41	0.08	0.13

TABLE 13

CORRELATION BETWEEN SYSTOLIC BLOOD PRESSURE AND SEVERAL VARIABLES

IN FEMALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
No. of cases	14	20	22	29	35	21	14
Height	0.10	0.40	0.58	0.36	0.45	0.56	-0.33
Weight	-0.03	0.18	0.41	0.26	0.42	0.23	0.30
Quetelet Index	-0.08	0.02	0.23	0.09	0.26	0.05	0.39
Triceps Skinfold	-0.36	-0.34	0.29	-0.07	-0.13	0.23	0.28
Subscapular Skinfold	-0.24	0.05	0.21	0.08	0.10	0.13	0.27
Upper Arm Circumference	-0.25	0.06	0.28	0.15	0.03	0.30	0.46

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TABLE 14

CORRELATION BETWEEN DIASTOLIC (4TH PHASE) BLOOD PRESSURE AND SEVERAL VARIABLES IN MALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
No. of cases	14	28	21	35	34	22	11
Height	0.64	0.22	0.08	0.09	0.06	0.38	0.38
Weight	0.49	0.16	0.02	-0.03	0.11	0.18	0.23
Quetelet Index	0.17	0.05	0.08	0.10	0.14	0.05	0.13
Triceps Skinfold	0.25	0.30	0.02	0.12	0.10	0.05	0.49
Subscapular Skinfold	0.38	0.22	0.05	-0.12	0.14	0.23	0.64
Upper Arm Circumference	0.48	0.09	-0.16	-0.02	0.18	0.16	0.23

TABLE 15

CORRELATION BETWEEN DIASTOLIC (4TH PHASE) BLOOD PRESSURE AND SEVERAL VARIABLES IN FEMALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
No. of Cases	14	20	22	29	35	21	14
Height	0.72	0.45	0.20	0.24	0.01	0.45	0.08
Weight	0.45	0.32	0.12	0.37	0.27	0.40	0.52
Quetelet Index	-0.08	0.17	0.03	0.28	0.32	0.27	0.51
Triceps Skinfold	0.02	0.05	0.07	0.14	0.07	0.22	0.32
Subscapular Skinfold	0.06	0.11	0.12	0.37	0.29	0.40	0.47
Upper Arm Circumference	0.12	0.30	0.04	0.31	0.12	0.30	0.55

-Correlation between upper arm circumference and diastolic (4th phase) blood pressure

The correlation coefficients for diastolic (4th phase) blood pressure and upper arm circumference for male and female age groups are shown in Tables 14 and 15. For males, the 5 - 6 age group showed the strongest correlation (0.48). Positive correlations were obtained for the 7 - 8, 13 - 14, 15 - 16, and 17 - 18 age groups. Negative correlations were obtained for the 9 - 10 and 11 - 12 year age groups.

In Table 15 the correlation coefficients for females show that the strongest correlation was 0.55 for the 17 - 18 year age group. The weakest correlation was 0.04 for females in the 9 - 10 year age group. All other correlations in this sex group were positive.

c) Electrocardiographic Characteristics

(i) Resting Heart Rate

Electrocardiograms were obtained from a total of 320 children and adolescents. However, eight of these electrocardiograms were eliminated from the analysis because of the poor quality of the recording.

Tables 16 and 17 show the mean and standard deviation of resting heart rate by sex and two-year age groups for 314 subjects, 5 - 18 years of age. For males the mean heart rate ranged from 70.3 beats per minute for the 17 - 18 year age group to 99.2 beats per minute for the 5 - 6 year age group. Heart rate decreased with increase in age.

For females the mean resting heart rate ranged from 77.5 beats per minute for the 17 - 18 year age group to 98.1 beats per minute for the 5 - 6 year age group. There was a tendency for resting heart rate to decrease with increase in age. However, for the 9 - 10 year age group a more conspicuous decrease was observed.

The mean resting heart rate was higher for females than males belonging to the 7 - 8, 11 - 12, 13 - 14, 15 - 16 and 17 - 18 year age groups. Males in the 5 - 6 and 9 - 10 year age groups had higher mean heart rates than females in the same age group.

(ii) Correlation Between Resting Heart Rate and Blood Pressure

-Correlation between resting heart rate and systolic blood pressure

The strongest correlation between resting heart rate and systolic blood pressure for males was 0.58 for the 9 -10 year age group. A negative correlation was observed for the 11 - 12 year age group. All other correlation coefficients were positive for the remaining age groups (Table 18).

For females the strongest correlation (0.22) was obtained for the 7 - 8 year age group. The weakest correlation (0.04) was obtained for the 11 - 12 year age group. For all the remaining age groups the correlation coefficients were positive (Table 18).

With the exception of the 11 - 12 year age group, all male groups showed a stronger positive correlation between resting heart and systolic blood pressure than corresponding female age groups (Table 18).

-Correlation between resting heart rate and diastolic (4th phase) blood pressure

For males, the correlation between resting heart rate and diastolic (4th phase) blood pressure was strongest (0.50) in the 9 - 10 year age group. The weakest correlation was 0.03 in the 7 - 8 year age group. Correlation coefficients were positive for all the remaining age groups (Table 19).

The strongest correlation in females was 0.36 in the 9 - 10 year age group. The weakest correlation was 0.01 in the 5 - 6 year age group. Correlations between resting heart rate and diastolic (4th phase) blood pressure were stronger in 5 - 6, 9 - 10, and 15 - 16 male age groups than corresponding female age groups. The female age groups which had stronger correlations than corresponding male groups were the 7 - 8, 11 - 12, 13 - 14, and 17 - 18 year age groups (Table 19).

(iii) Amplitude of P Wave in Lead II

The mean and standard deviation of the amplitude of P wave in Lead II by sex and two year age groups are shown in Tables 16 and 17. The mean amplitude of the two year age groups for males ranged from 0.5 mm to 0.8 mm. Males in the 7 - 8 age group had the lowest P wave amplitude followed by those in the 9 - 10 age group which had a value of 0.6 mm. Those in the 11 - 12 and 17 - 18 age groups had a value of 0.7 mm. The highest value was in the 5 - 6, 13 - 14 and 15 - 16 year age groups (Table 16). Similar results were obtained for females in the different age groups (Table 17).

(iv) Correlation Between Amplitude of P Wave in Lead II and Blood Pressure

-Correlation between amplitude of P wave in lead II and systolic pressure

Table 18 shows the correlation coefficients obtained for amplitude of P wave in lead II and systolic blood pressure for the two year age groups in males and females. The strongest correlation in males (0.64) was in the 17 - 18 year age group. The weakest correlation was 0.20 in the 13 - 14 year age group. All other age groups had positive correlations.

For females the 17 - 18 year age group had the strongest correlation (0.48). The weakest correlation was 0.12 in the 7 - 8 year age group. Correlation coefficients were positive for the remaining age groups (Table 18).

-Correlation between amplitude of P wave in lead II and diastolic (4th phase) blood pressure

The correlations between amplitude of P wave in lead II and diastolic (4th phase) blood pressure are indicated in Table 19. For males the strongest correlation (0.41) was in the 11 - 12 year age group. Males in the 17 - 18 year age group had the weakest correlation (0.14).

For females the strongest correlation was 0.33 in the 11 - 12 year age group. The weakest correlation was 0.12 in the 17 - 18 year age group.

In all age groups, except 13 - 14, the correlation coefficients were stronger for males than for females for the correlation between amplitude of P wave in lead II and diastolic blood

pressure (Table 19).

(v) Amplitude of R Wave in Lead II

Tables 16 and 17 show the mean and standard deviation of the amplitude of R wave in lead II for males and females according to two year age groups. The maximum value for males was 11.8 mm in the 13 - 14 year age group. The minimum value was 6.5 mm in the 5 - 6 year age group. For females the maximum value was 11.0 mm in the 17 - 18 year age group, the minimum value was 5.8 mm in the 7 - 8 year age group. Males in the 7 - 8, 13 - 14, and 15 - 16 year age groups had higher amplitudes of R wave in lead II than females in corresponding age groups. Females in the 5 - 6, 9 - 10, 11 - 12, and 17 - 18 year age groups had higher amplitude of R wave in lead II than males in corresponding age groups.

(vi) Correlation Between Amplitude of R Wave in Lead II and Blood Pressure

-Correlation between amplitude of R wave in lead II and systolic blood pressure

For males the strongest correlation between amplitude of R wave in lead II and systolic blood pressure was 0.88 in the 17 - 18 year age group. The weakest correlation was 0.08 for the 11 - 12 year age group. Correlation coefficients were positive for each male age group (Table 18).

For females, 0.31 for the 13 - 14 year age group was the strongest correlation coefficient obtained. The weakest correlation obtained was 0.04 for the 5 - 6 and 7 - 8 year age groups, respectively.

Males in the 5 - 6, 7 - 8, 11 - 12, 15 - 16, and 17 - 18 year age groups had stronger correlation between amplitude of R wave

and systolic blood pressure than females in similar age categories. Females in the 9 - 10 and 13 - 14 age categories had stronger correlations than males in similar age categories (Table 18).

-Correlations between amplitude of R wave in lead II and diastolic (4th phase) blood pressure

Correlations between amplitude of R wave in lead II and diastolic (4th phase) blood pressure for males show that the 9 - 10 year age group have the strongest correlation (0.45) (Table 19). The weakest correlation was 0.02 for the 11 - 12 year age group. All correlations were positive for the male age groups.

For females the strongest correlation (0.18) was in the 13 - 14 year age group. The weakest correlation (0.08) was in the 9 - 10 year age group (Table 19). Males in all age categories, except the 11 - 12, had stronger correlations between amplitude of R wave in lead II and diastolic (4th phase) blood pressure.

d) Family Size and Blood Pressure

(i) Correlation Between Family Size and Blood Pressure

-Correlation between family size and systolic blood pressure

As indicated in Table 20, the strongest correlation between family size and systolic blood pressure, for males, was 0.29 in the 17 - 18 year age group. Negative correlations were observed for the 5 - 6 and 15 - 16 year age groups. All other male age groups had positive correlations.

For females, the 5 - 6 year age group had the strongest correlation between family size and systolic blood pressure (0.47). The correlations were negative for the 7 - 8 and 13 - 14 year age groups. The other correlations obtained were positive (Table 20).

TABLE 16

ELECTROCARDIOGRAPHIC CHARACTERISTICS OF MALES

BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
No. of Subjects	13	27	21	33	32	22	11
Resting Heart Rate (beats/min)							
Mean	99.2	88.6	87.1	81.3	77.5	77.2	70.3
S.D.	15.3	9.7	17.1	17.7	14.9	19.6	17.4
Amplitude of P Wave (mm) in Lead II							
Mean	0.8	0.5	0.6	0.7	0.8	0.8	0.7
S.D.	0.4	0.1	0.3	0.3	0.8	0.3	0.5
Amplitude of R Wave (mm) in Lead II							
Mean	6.5	7.1	8.1	9.8	11.8	11.1	9.6
S.D.	2.6	3.4	3.7	4.0	4.6	5.2	6.0

TABLE 17

ELECTROCARDIOGRAPHIC CHARACTERISTICS OF FEMALES

BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
No. of Subjects	13	19	22	29	35	21	14
Resting Heart Rate (beats/min)							
Mean	98.1	90.3	82.6	86.0	85.1	80.1	77.5
S.D.	7.5	8.4	14.0	13.3	17.0	10.9	18.0
Amplitude of P Wave (mm) in Lead II							
Mean	0.8	0.5	0.6	0.7	0.8	0.8	0.7
S.D.	0.4	0.1	0.2	0.2	0.3	0.3	0.3
Amplitude of R Wave (mm) in Lead II							
Mean	7.0	5.8	8.5	10.1	9.6	8.4	11.0
S.D.	3.0	3.5	3.7	3.7	4.2	3.6	5.5

TABLE 18

CORRELATION OF SYSTOLIC BLOOD PRESSURE WITH VARIOUS ELECTROCARDIOGRAPHIC CHARACTERISTICS OF MALES AND FEMALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
MALES							
No. of Cases	13	27	21	33	32	22	11
Resting Heart Rate	0.43	0.41	0.58	-0.16	0.44	0.24	0.50
Amplitude of P Wave in Lead II	0.31	0.30	0.22	0.41	0.20	0.31	0.64
Amplitude of R Wave in Lead II	0.17	0.44	0.09	0.08	0.09	0.34	0.88
FEMALES							
No. of Cases	13	19	22	29	35	21	14
Resting Heart Rate	-0.22	0.22	0.06	0.04	0.20	0.16	0.21
Amplitude of P Wave in Lead II	0.16	0.12	0.15	0.19	0.23	0.25	0.48
Amplitude of R Wave in Lead II	0.04	0.04	0.25	0.05	0.31	0.09	0.06

TABLE 19

CORRELATION OF DIASTOLIC (4TH PHASE) BLOOD PRESSURE WITH VARIOUS ELECTROCARDIOGRAPHIC CHARACTERISTICS OF MALES AND FEMALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
MALES							
No. of Cases	13	27	21	33	32	22	11
Resting Heart Rate	0.45	0.03	0.50	0.06	0.21	0.46	0.12
Amplitude of P Wave in Lead II	0.23	0.31	0.26	0.41	0.31	0.17	0.14
Amplitude of R Wave in Lead II	0.26	0.30	0.45	0.02	0.22	0.31	0.42
FEMALES							
No. of Cases	13	19	22	29	35	21	14
Resting Heart Rate	0.01	0.05	0.36	0.10	0.30	0.29	0.30
Amplitude of P Wave in LeadII	0.22	0.14	0.15	0.33	0.18	0.22	0.12
Amplitude of R Wave in Lead II	0.13	0.10	0.08	0.15	0.18	0.11	0.11

-Correlation between family size and diastolic (4th phase) blood pressure

Table 21 shows the results of the correlation between family size and diastolic (4th phase) blood pressure. For males, negative correlations were obtained for all age groups, except the 7 - 8 and 9 - 10 year age groups which had correlations of 0.20 and 0.29 respectively.

As shown in Table 21, 0.47 in the 11 - 12 year age group was the strongest correlation for females. Negative correlations occurred in the 7 - 8, 13 - 14 and 15 - 16 year age groups. The correlations were positive for the other age groups (5 - 6, 9 - 10 and 17 - 18).

e) Birth Order and Blood Pressure

(i) Correlation Between Birth Order and Blood Pressure

-Correlation between birth order and systolic blood pressure

The results of the correlation between birth order and systolic blood pressure are indicated in Table 20. For males the strongest positive correlation was 0.18 for the 17 - 18 year age group. Negative correlations were obtained for the 5 - 6 and 15 - 16 year age groups. All other male age groups had positive correlations between birth order and systolic blood pressure.

Among the female age groups, the 5 - 6 year age group had the strongest correlation (0.69) between birth order and systolic blood pressure. Negative correlations were obtained for the 7 - 8, 13 - 14 and 17 - 18 year age groups. The correlation coefficients were positive for the other age groups (9 - 10, 11 - 12 and 15 - 16) (Table 20).

-Correlation between birth order and diastolic (4th phase) blood pressure

The correlation between birth order and diastolic (4th phase) blood pressure, for males, shows that most of the age groups had negative correlations. The exceptions were the 9 - 10 and 15 - 16 year age groups which had positive correlations of 0.07 and 0.18 respectively (Table 21).

Among the female age groups, the 5 - 6 year age group had the strongest correlation (0.32) between birth order and diastolic (4th phase) blood pressure. Negative correlations were obtained for the 7 - 8, 13 - 14, and 15 - 16 year age groups. The remaining age groups 9 - 10, 11 - 12 and 17 - 18 had positive correlations (Table 21).

Summary

Tables 22 and 23 summarise the correlation between systolic blood pressure and the eleven variables which were studied. It can be seen from this table that systolic blood pressure was positively related to amplitude of P wave in lead II and amplitude of R wave in lead II for all age groups in each sex. Height, weight, Quetelet Index, upper arm circumference, as well as resting heart rate were found to be positively associated with systolic blood pressure in 6 of the 7 age groups of each sex. Triceps skinfold, subscapular skinfold and family size correlated positively with systolic blood pressure in 5 of the 7 age groups in each sex. Birth order was positively related to systolic blood pressure in 5 of the 7 male age groups, but was only positively related to systolic blood pressure in 4 of the 7 female age groups.

In Tables 24 and 25, a summary is shown of the correlation

TABLE 20

CORRELATION OF SYSTOLIC BLOOD PRESSURE WITH FAMILY SIZE AND BIRTH ORDER OF MALES AND FEMALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
MALES							
No. of Cases	14	28	21	33	34	22	11
Family Size	-0.19	0.01	0.15	0.06	0.15	-0.27	0.29
Birth Order	-0.41	0.15	0.13	0.08	0.17	-0.24	0.18
FEMALES							
No. of Cases	14	20	22	29	35	21	14
Family Size	0.47	-0.06	0.19	0.37	-0.21	0.11	0.04
Birth Order	0.69	-0.12	0.17	0.14	-0.19	0.06	-0.02

TABLE 21

CORRELATION OF DIASTOLIC (4TH PHASE BLOOD PRESSURE TO FAMILY SIZE AND BIRTH ORDER OF MALES AND FEMALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
MALES							
No. of Cases	14	28	21	33	34	22	11
Family Size	-0.10	0.20	0.29	-0.14	-0.18	-0.21	-0.39
Birth Order	-0.23	-0.02	0.07	-0.16	-0.09	0.18	-0.39
FEMALES							
No. of Cases	14	20	22	29	35	21	14
Family Size	0.47	-0.06	0.19	0.37	-0.21	0.11	0.04
Birth Order	0.69	-0.12	0.17	0.14	-0.19	0.06	-0.02

between diastolic (4th phase) blood pressure and the eleven variables studied. From this Table it can be seen that height, triceps skinfold thickness, resting heart rate, amplitude of P wave and amplitude of R wave were positively correlated with diastolic (4th phase) blood pressure in all age groups of each sex.

Weight was positively correlated with diastolic (4th phase) blood pressure for all female age groups. Among the male age groups positive correlations were obtained in 6 of the 7 age groups. Quetlet Index was positively correlated with diastolic (4th phase) blood pressure for all male age groups. For females positive correlations were obtained for 6 of the 7 age groups.

Subscapular skinfold and upper arm circumference were positively correlated with diastolic (4th phase) blood pressure in all of the female age groups but such correlations were obtained in only 5 of the 7 male age groups. In females family size was positively correlated with diastolic (4th phase) blood pressure in 5 of the 7 age groups. Two of the 7 male age groups showed positive correlation between family size and diastolic (4th phase) blood pressure. Birth order was positively correlated with diastolic (4th phase) blood pressure in 4 of the 7 female age groups; in the male age groups only 2 of the 7 showed positive correlations.

Multiple Linear Regression Analysis

As mentioned in the Method of Data Analysis (page 59) ANOVA tests were carried out on the 5 - 12 and 13 - 18 year age groups to test the null hypothesis that there was no dependence of blood pressure on the independent variables. The results of these tests were highly significant, as indicated below, therefore the null hypothesis was

TABLE 22

SUMMARY OF CORRELATION BETWEEN SYSTOLIC BLOOD PRESSURE AND VARIABLES STUDIED FOR MALES BY TWO YEAR AGE GROUPS*

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
Height	+	+	+	+	+	+	-
Weight	+	+	+	+	+	+	-
Quetelet Index	-	+	+	+	+	+	+
Triceps Skinfold	-	+	+	-	+	+	+
Subscapular Skinfold	-	+	+	-	+	+	+
Upper Arm Circumference	+	+	+	-	+	+	+
Resting Heart Rate	+	+	+	-	+	+	+
Amplitude of P Wave in Lead II	+	+	+	+	+	+	+
Amplitude of R Wave in Lead II	+	+	+	+	+	+	+
Family Size	-	+	+	+	+	-	+
Birth Order	-	+	+	+	+	-	+

* + = positive correlation

- = negative correlation

TABLE 23

SUMMARY OF THE CORRELATION BETWEEN SYSTOLIC BLOOD PRESSURE AND VARIABLES FOR FEMALES BY TWO YEAR AGE GROUPS

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
Height	+	+	+	+	+	+	-
Weight	-	+	+	+	+	+	+
Quetlet Index	-	+	+	+	+	+	+
Triceps Skinfold	-	-	+	-	-	+	+
Subscapular Skinfold	-	+	+	+	+	+	+
Upper Arm Circumference	-	+	+	+	+	+	+
Resting Heart Rate	-	+	+	+	+	+	+
Amplitude of P Wave in Lead II	+	+	+	+	+	+	+
Amplitude of R Wave in Lead II	+	+	+	+	+	+	+
Family Size	+	-	+	+	-	+	+
Birth Order	+	-	+	+	-	+	-

* + = positive correlation

  - = negative correlation

TABLE 24

SUMMARY OF THE CORRELATION BETWEEN DIASTOLIC (4TH PHASE) BLOOD PRESSURE AND VARIABLES STUDIED FOR MALES BY TWO YEAR AGE GROUPS*

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
Height	+	+	+	+	+	+	+
Weight	+	+	+	-	+	+	+
Quetelet Index	+	+	+	+	+	+	+
Tricept Skinfold	+	+	+	+	+	+	+
Subscapular Skinfold	+	+	-	-	+	+	+
Upper Arm Circumference	+	+	-	-	+	+	+
Resting Heart Rate	+	+	+	+	+	+	+
Amplitude of P Wave in Lead II	+	+	+	+	+	+	+
Amplitude of R Wave in Lead II	+	+	+	+	+	+	+
Family Size	-	+	+	-	-	-	-
Birth Order	-	-	+	-	-	+	-

* + = positive correlation

- = negative correlation

TABLE 25

SUMMARY OF THE CORRELATION BETWEEN DIASTOLIC (4TH PHASE) BLOOD PRESSURE AND VARIABLES STUDIED FOR FEMALES BY TWO YEAR AGE GROUPS*

	Age Groups (Years)						
	5-6	7-8	9-10	11-12	13-14	15-16	17-18
Height	+	+	+	+	+	+	+
Weight	+	+	+	+	+	+	+
Quetelet Index	-	+	+	+	+	+	+
Triceps Skinfold	+	+	+	+	+	+	+
Subscapular Skinfold	+	+	+	+	+	+	+
Upper Arm Circumference	+	+	+	+	+	+	+
Resting Heart Rate	+	+	+	+	+	+	+
Amplitude of P Wave in Lead II	+	+	+	+	+	+	+
Amplitude of R Wave in Lead II	+	+	+	+	+	+	+
Family Size	+	-	+	+	-	+	+
Birth Order	+	-	+	+	-	+	-

* + = positive correlation

- = negative correlation

rejected.

In the 5 - 12 age group with systolic and diastolic (4th phase) blood pressure respectively as the dependent variables, F values of 4.44 ($p < 0.001$) and 3.67 ($p < 0.001$) were obtained (Appendix E). In the 13 - 18 year age group with systolic and diastolic (4th phase) blood pressure respectively as the dependent variables, F values of 2.66 ($p < 0.01$) and 3.62 ($p < 0.001$) were obtained (Appendix E).

These results indicate that the systolic and diastolic (4th phase) blood pressures of both groups were dependent on one or more of the independent variables.

These results of the multiple linear regression analysis indicated which of the independent variables were determinants of blood pressure levels in the two groups.

a) Determinants of Systolic Blood Pressure

In the 5 - 12 year age group, positive significant determinants of systolic blood pressure were (Table 26) height ($p < 0.001$), resting heart rate ($p < 0.001$), amplitude of P wave in lead II ($p < 0.002$) and family size ($p < 0.05$). Triceps skinfold thickness had a negative significant effect on systolic blood pressure in this age group.

In the 13 - 18 year age group, positive significant determinants of systolic blood pressure were resting heart rate ($p < 0.001$), amplitude of P wave in lead II ($p < 0.001$), and amplitude of R wave in lead II ($p < 0.001$) (Table 27).

b) Determinants of Diastolic (4th phase) Blood Pressure

Positive significant determinants of diastolic (4th phase) blood pressure in the 5 - 12 year age group, were resting heart rate

($p < 0.001$), amplitude of P wave in lead II ($p < 0.01$) and family size ($p < 0.001$). Birth order had a negative significant effect ($p < 0.001$) on diastolic (4th phase) blood pressure in this age group (Table 28).

In the 13 - 18 year age group, subscapular skinfold thickness ($p < 0.005$), resting heart rate ($p < 0.001$) and amplitude of P wave in lead II ($p < 0.05$) were positive significant determinants of diastolic (4th phase) blood pressure. Family size had a negative significant effect ($p < 0.002$) (Table 29).

TABLE 26

VARIABLES INFLUENCING SYSTOLIC BLOOD PRESSURE IN SDU

IN CHILDREN 5 - 12 YEARS OF AGE

BY MULTIPLE LINEAR REGRESSION ANALYSIS

INDEPENDENT VARIABLES	PARTIAL REGRESSION COEFFICIENT	STANDARD ERROR	p
Height SDU	0.672	0.327	<0.001
Weight SDU	-0.674	0.620	N.S.
Quetelet SDU	0.481	0.455	N.S.
Triceps Skinfold Thickness	0.028	0.018	<0.05
Subscapular Skinfold Thickness	0.010	0.015	N.S.
Upper Arm Circumference	0.016	0.053	N.S.
Resting Heart Rate	0.017	0.005	<0.001
Amplitude of P Wave in Lead II	0.699	0.261	<0.001
Amplitude of R Wave in Lead II	0.034	0.020	<0.002
Family Size	0.084	0.058	<0.05
Birth Order	-0.057	0.060	N.S.

Constant = -2.596

TABLE 27

VARIABLES INFLUENCING SYSTOLIC BLOOD PRESSURE IN SDU

IN ADOLESCENTS 13 - 18 YEARS OF AGE

BY MULTIPLE LINEAR REGRESSION ANALYSIS

INDEPENDENT VARIABLES	REGRESSION COEFFICIENT	STANDARD ERROR	p
Height SDU	0.278	0.242	N.S.
Weight SDU	-0.191	0.577	N.S.
Quetelet SDU	0.472	0.490	N.S.
Triceps Skinfold Thickness	-0.008	0.017	N.S.
Subscapular Skinfold Thickness	-0.003	0.019	N.S.
Upper Arm Circumference	-0.019	0.043	N.S.
Resting Heart Rate	0.012	0.005	<0.001
Amplitude of P Wave in Lead II	0.411	0.176	<0.001
Amplitude of R Wave in Lead II	0.037	0.018	<0.001
Family Size	-0.010	0.048	N.S.
Birth Order	-0.021	0.048	N.S.

Constant = -0.205

TABLE 28

VARIABLES INFLUENCING DIASTOLIC (4TH PHASE) BLOOD PRESSURE IN SDU IN CHILDREN 5 - 12 YEARS OF AGE BY MULTIPLE LINEAR REGRESSION ANALYSIS

INDEPENDENT VARIABLES	PARTIAL REGRESSION COEFFICINET	STANDARD ERROR	p
Height SDU	-0.049	0.058	N.S.
Weight SDU	0.658	0.616	N.S.
Quetelet SDU	-0.418	0.452	N.S.
Triceps Skinfold Thickness	0.016	0.018	N.S.
Subscapular Skinfold Thickness	0.002	0.015	N.S.
Upper Arm Circumference	-0.045	0.053	N.S.
Resting Heart Rate	0.015	0.005	<0.001
Amplitude of P Wave in Lead II	0.421	0.259	<0.01
Amplitude of R Wave in Lead II	-0.006	0.019	N.S.
Family Size	0.186	0.058	<0.001
Birth Order	-0.154	0.060	<0.001

Constant = -1.526

TABLE 29

VARIABLES INFLUENCING DIASTOLIC (4TH PHASE) BLOOD PRESSURE IN SDU IN ADOLESCENTS 13 - 18 YEARS OF AGE BY MULTIPLE LINEAR REGRESSION ANALYSIS

INDEPENDENT VARIABLES	PARTIAL REGRESSION COEFFICIENT	STANDARD ERROR	p
Height SDU	0.300	0.234	N.S.
Weight SDU	-0.543	0.558	N.S.
Quetelet SDU	0.585	0.474	N.S.
Triceps Skinfold Thickness	-0.027	0.016	N.S.
Subscapular Skinfold Thickness	0.045	0.018	<0.005
Upper Arm Circumference	0.005	0.042	N.S.
Resting Heart Rate	0.014	0.005	<0.001
Amplitude of P Wave in Lead II	0.242	0.165	<0.05
Amplitude of R Wave in Lead II	0.009	0.017	N.S.
Family Size	-0.083	0.046	<0.002
Birth Order	0.006	0.046	N.S.

Constant = -1.118

CHAPTER 6

DISCUSSION

INTRODUCTION

The results of this study will be discussed in the following four sections:

1. Prevalence of Hypertension;
2. Familial Aggregation of Blood Pressure;
3. "Tracking" of Blood Pressure;
4. Factors Associated With Blood Pressure Levels in Children and Adolescents 5 - 18 Years of Age

SECTION 1

Prevalence of Hypertension

Both epidemiological and clinical observations have shown that primary hypertension is an extremely common problem among adults. However, primary hypertension can be predicted and in cases where it is untreated, it can be the cause of strokes, coronary heart disease, and kidney failure (68). These observations made among the adult population have led researchers to investigate blood pressure levels in children with the idea that it might be possible to identify potential or actual hypertensives at an early stage in life.

In this study the criteria used to define hypertension was blood pressure ≥ 2 SDU above the mean of a subject's age and sex group. Blood pressure scores ≥ 1 and < 2 SDU were used to indicate "high normal" blood pressure.

It is obvious that this is an arbitrary division made for epidemiological purposes. Furthermore, the difficulties of defining

what levels of blood pressure constitute primary hypertension are well known. A large part of the famous controversy about the nature of hypertension between Platt (69) and Pickering (70) centered around this problem.

However, even Pickering (71) who is an ardent opponent of the drawing of cutting lines in a normally distributed quantitative biological variable such as blood pressure, recognises the need to establish certain criteria as a guide for action.

Whether or not blood pressure values are normally distributed, it would be a dangerous oversimplification to equate blood pressure values with, for example, body height. While the variation in body height may be of academic or aesthetic interest only, the variation in blood pressure values cannot be treated as such. It is acknowledged that increased blood pressure leads to very significant changes in the circulatory system that can have serious consequences.

From this point of view, the definition of hypertension as ≥ 2 SDU was certainly a conservative one possessing biological and medical significance.

Using the above criteria for hypertension the prevalence of systolic hypertension was 1.6%. The prevalence of diastolic hypertension was also 1.6% (Table 4). The finding in this study that 1.6% of the subjects had systolic or diastolic (4th phase) blood pressure values ≥ 2 SDU would suggest that action should be taken to identify these subjects and re-measure their blood pressure. If they still maintain high blood pressure levels, then it would be necessary to refer them to a physician for medical supervision. Such action is

warranted since primary hypertension is associated with progressive vascular disease.

As indicated in Table 1, several researchers have found that primary hypertension does exist among children and adolescents. However, the prevalence of primary hypertension in this sector of the population tended to vary and comparison of figures obtained in this study with those reported in the various studies (Table 1) would be inappropriate for several reasons. The most important of which are the differences in methods used in these studies to obtain relevant data. In some studies different diastolic signals, for example, 4th and 5th phase were used. Also the position of the subject during the taking of blood pressure measurements tended to be different. The number of readings taken and the cuff sizes used also varied from study to study.

According to the criteria stated above for "high normal" blood pressure, 14.4% of the subjects in this study had "high normal" systolic blood pressure for their age and sex group and 15.3% had "high normal" diastolic (4th phase) blood pressure for their age and sex group (Table 4).

Studies on young and middle-aged persons have shown that those with "high normal" blood pressures continue to exhibit with time a tendency toward higher pressures (48, 57) and may be manifesting an early phase of primary hypertension. Whether or not the subjects in this study with blood pressure levels ≥ 1 SDU above the mean of their age and sex group will, in fact, develop hypertension when they reach middle age cannot be determined now. However, it would be

worthwhile to re-measure the blood pressure of these subjects with "high normal" blood pressure some time in the future to find out whether the tendency for higher pressures continue to persist.

As a result of these findings, a study has been initiated to find out whether those subjects who have been designated as hypertensives and as having "high normal" blood pressures belong to families with one or more hypertensive parents. It has been shown that a tendency toward higher pressures occurs in young people belonging to families with one or two hypertensive parents (9).

SECTION 2

Familial Aggregation of Blood Pressure

There is evidence to suggest that blood pressure levels are aggregated within families. Klein *et al* (60) found a significant aggregation of blood pressure based upon the findings of 124 children, aged 1 to 14 years, from 44 families with at least two siblings. A significant aggregation was not found, however, when newborn infants were studied.

Zinner *et al* (9) have also reported a tendency toward familial aggregation of blood pressure. Their study included 326 children aged 2 to 14 years and their mothers. They found that the familial aggregation was present by the age of two years. In addition, it persisted on re-examination four years later.

The results of this study into the familial aggregation of blood pressure of 259 subjects, 5 - 18 years of age, belonging to 85 families, each of which had two or more siblings, supports those reported in the studies above (60, 9).

The findings of this study (Table 5) indicate that there was a strong significant ($p < 0.01$) aggregation of systolic, as well as diastolic (4th phase) blood pressure within those families that were studied.

This tendency for blood pressure to cluster or aggregate within families would suggest that blood pressure levels are affected by environmental or genetic factors. However, in the study by Klein *et al* (60) no significant aggregation of blood pressure within families was found newborn infants were added to the families. Based on the results of this study by Klein *et al* (60), it would appear that the significant aggregation of blood pressure found within families might be explained by environmental factors.

In addition, the fact that familial aggregation of blood pressure has been documented in this and other studies would suggest that the studying of familial aggregation of blood pressure might be a useful way of identifying those families which are at a higher risk of experiencing hypertension. This would facilitate the implementation of effective preventive measures.

SECTION 3

"Tracking" of Blood Pressure

It is important to establish whether blood pressure readings taken in childhood are predictive of blood pressure levels later on in life. If this were found to be the case, then it would be possible to identify future hypertensives in childhood.

One way of finding out whether blood pressure levels observed in childhood are predictive of blood pressure levels later

in life is to study the "tracking" of blood pressure. "Tracking" of blood pressure means that one's blood pressure has entered on a "track" which might be high for age or low for age, and it continues along the track with time, so that higher pressures remain higher and lower pressures remain lower.

Since among adults there is not usually a crisis onset of high blood pressure, and if the "tracking" phenomenon is a true one, it is reasonable to assume that children with relatively high blood pressures for their age, even though still within the normal range, would be more likely to develop primary hypertension when they reach middle age. This possibility is reflected in the fact that young and middle-aged persons who were found to have high normal levels of blood pressure for their age and sex group tended to show a steeper slope of blood pressure increase over the next years and decades than those with low and medium normal pressures (48, 57).

The results of the "tracking" study reported in this dissertation indicate that there was a significant tracking ($p < 0.00002$) of systolic blood pressure (Figure 4). The systolic blood pressure measurements taken on 68 subjects who had been measured two years earlier indicated that of those who, two years earlier, had systolic blood pressure scores greater than 1.0 SDU above the mean of their age and sex group, 71% of them continued to have positive SDU scores at follow-up. Of those who, at the time of the initial study, had systolic scores less than 1.0 SDU below the mean, 78% continued to have negative follow-up scores (Table 6).

These results can be interpreted to mean that in this group of subjects, systolic blood pressure levels obtained two years later

were significant and positively related to the systolic blood pressure measurements taken two years earlier.

The results of this study also indicate that there was a significant "tracking" ($p < 0.05$) of diastolic (4th phase) blood pressure (Figure 6). However, as the regression coefficients indicate, (Figures 4 and 6) the "tracking" of diastolic (4th phase) blood pressure was not as strong as that observed for systolic blood pressure. Of eight subjects with initial diastolic scores greater than 1.0 SDU above the mean of their age and sex group, 88% had positive follow-up scores. Of the 13 who had initial diastolic scores of less than 1.0 SDU below the mean of their age and sex group, 69% of them had negative scores at follow-up (Table 7).

Zinner *et al* (10) also found a weaker "tracking" effect for diastolic blood pressure in their study. One of the conclusions made in their study was that stratification of blood pressure within peer groups begins and is detectable in childhood. In another study, Buck (52) studied children from ages 5 to 12 years and found that those who had systolic and diastolic blood pressures greater than the 90th percentile at 5 years of age had a statistically significant elevation of both systolic and diastolic pressures at age 12 years when compared to age-matched controls.

The importance of carrying out studies on the "tracking" of blood pressure was demonstrated by the study in Evans County, Georgia, in 1961 (51). In this study, 11% of 435 adolescents were labelled as hypertensives ($\geq$140 mmHg systolic and/or $\geq$90 mmHg diastolic) with one blood pressure measurement. Seven years later, 30 of these

hypertensives were evaluated. It was found that sustained hypertension developed in five of them and six had sustained hypertension with vascular complications. Two of them died from cerebral hemmorrhage, which was verified by autopsy.

The results of the above study show that the relatively high blood pressure values observed at an early age can be of clinical significance. In order to prevent such occurrences, it would be necessary to re-measure, in the future, the blood pressure of those subjects who in this study were found to have blood pressure scores greater than 1 SDU during the initial and follow-up studies.

In summary, there is evidence from this and other studies mentioned above to suggest that "tracking" of blood pressure is a real phenomenon, which may be useful in helping to identify those subjects belonging to a high risk group. This high risk group would then be the target for preventive measures.

SECTION 4

Factors Associated With Blood Pressure Levels in Children and Adolescents 5 - 18 Years of Age

a) Introduction

Few epidemiological studies have attempted to identify factors which might be associated with blood pressure levels in children and adolescents. In cases where such studies have been undertaken, the methods used to obtain the relevant data varied considerably making comparison of results with this study inappropriate. In this study, several factors were investigated and shown to be related to the blood pressure levels obtained with the Physiometrics Automatic

Blood Pressure Recorder.

b) Sex and Age

(i) Systolic Blood Pressure

As indicated in Figure 7, systolic blood pressure increased with age in both sexes. This increase was regular for females; however, in the case of males, it was slightly irregular. The differences in systolic blood pressure between the age groups 5 - 6 and 13 - 14 of both sexes was small. The difference was more conspicuous for the 15 - 16 and 17 - 18 year age groups, where males had higher systolic blood pressures.

The increase of systolic blood pressure with age has been reported in other studies (50, 9, 43, 10, 6). It is difficult to compare the results obtained in this study for systolic blood pressure for male and female with those reported in the other studies because the stratification of subjects into age groups was different. Two studies (50, 43) used single age groups, while the others used different two year groupings (9, 10). However, it is generally accepted that there is little difference in systolic blood pressure between boys and girls under the age of 14 years; over the age of 14 year, girls show lower systolic blood pressure readings than boys (72). The findings of this study are similar.

(ii) Diastolic Blood Pressure

Diastolic (4th phase) blood pressure (Figure 7) increased almost linearly with age for females in the 5 - 16 year range, with a slight drop occurring in the 17 - 18 year age group. Males showed an irregular increase of diastolic (4th phase) blood pressure with age.

Increases with age were observed for the 5 - 6, 7 - 8 and 9 - 10 year age groups. There was a slight decrease in the 11 - 12 and 13 - 14 year age groups and an increase in the 15 - 16 and 17 - 18 year age groups.

Females in the 5 - 6, 13 - 14, and 15 - 16 year age groups had higher diastolic (4th phase) blood pressure than males in similar age groups. Males in the 7 - 8, 9 - 10, 11 - 12, and 17 - 18 year age groups had higher diastolic (4th phase) blood pressure than females in similar age groups.

The comparison of the findings of this study with other studies are difficult for the same reasons given for systolic blood pressure, that is, stratification of subjects into age groups was different. Also, in one study (43) both 4th and 5th phase diastolic signals were used to report diastolic blood pressure readings.

It is acknowledged, however, that between the ages of 5 - 14 years there are sex differences in diastolic blood pressure, but the pattern is not consistent and over the age of 14 years girls show lower diastolic blood pressure readings than boys (72). The results of this study showed no consistent differences for diastolic (4th phase) blood pressure readings between the sexes for all age groups (Table 9). However, in this study females in the 13 - 14 and 15 - 16 year age groups had higher diastolic (4th phase) blood pressure readings than males. This difference from the expected could be due to the fact that the examiner taking the blood pressure measurements was of the opposite sex. Comstock (73) in his data suggested that the blood pressure tended to be higher when the examiner was of the opposite

sex.

c) Summary

The difference in blood pressure levels observed in this study between males and females, particularly for systolic blood pressure, seems to reflect a developmental phenomen that is related to sexual maturation. It also appears as if the blood pressure of males exceeds that of females by the time they reach adulthood.

Finally, it should be stated that it would have been meaningless to compare blood pressure levels obtained in this study with those reported in other studies done in different geographical areas. The main reason for this lack of comparison as mentioned above was that different methodologies were used to obtain and present blood pressure levels.

Anthropometric Characteristics

a) Introduction

There are few epidemiological studies relating anthropometric measurements to blood pressure levels in children and adolescents. Of those studies mentioned in the review of the literature, one (6) reported correlations for blood pressure levels and anthropometric measurements using a 6 - 18 year age grouping. Another (62) grouped subjects into 7 - 9 and 10 - 12 year age categories. These differences in grouping of subjects makes it impossible to compare the results of this study with other studies. The only study which has grouped subjects into two year age intervals that corresponds to that used in

the present study is that reported by Miller and Shekelle (63). However, they studied only 15 - 16 year olds and took diastolic (5th phase) blood pressures.

b) Height

The finding that males were taller than females in all age groups (Tables 10 and 11), with a greater difference in height between the sexes occurring in the 15 - 16 and 17 - 18 year age groups, compares favourably with that reported by Watson and Lowrey (74) for American boys and girls between 5 and 17 years of age.

(i) Correlation Between Height and Blood Pressure

Positive correlations were obtained between height and systolic blood pressure for all age groups except the 17 - 18 year age groups of both sexes (Tables 12 and 13). In the case of diastolic (4th phase) blood pressure positive correlations were obtained for all age groups of both sexes (Tables 14 and 15).

The results of this study indicate that height is positvely related to systolic blood pressure up to about 16 years of age, after which there is a negative association. This relationship holds true for both sexes. Based upon these results it would appear that after 16 years of age other factors might play a more important role in the level of systolic blood pressure observed.

On the other hand, the relationship between height and diastolic (4th phase) blood pressure was positive in all age groups studies, which would suggest that unlike the case of systolic blood pressure, height continued to play a role in the level of diastolic (4th phase) blood pressure observed in the 17 - 18 year age group of

both sexes.

c) Weight

Males were heavier than females in all the age groups, except the 13 - 14 year age group. In the latter age group, females were 1.3 kilograms heavier than males (Tables 10 and 11). However, Watson and Lowrey (74) in their study of American children found that girls in single age groups between 7 and 14 years of age were slightly heavier than boys in the same age range.

These differences in finding might be explained by differences in genealogy.

(i) Correlation Between Weight and Blood Pressure

In this study weight was positively correlated with both systolic and diastolic (4th phase) blood pressure in almost all age groups of both sexes (Tables 12, 13, 14 and 15). Positive correlations between weight and blood pressure in young populations have also been observed by Londe and Goldring (75), Levy *et al* (76), and Court *et al* (77).

It has been shown that persons overweight as children, teenagers or young adults are likely to remain so or become more overweight throughout life (78). Also, the relation between blood pressure and body weight has been shown to be greater in those with a family history of obesity and hypertension (75, 76).

The findings of this and other studies referred to above provide substantial evidence in support of the view that blood pressure and body weight are positively correlated.

(ii) Correlation Between Quetelet Index (wt/ht^2) and Blood Pressure

Since crude weight varies greatly with height and age and

may reflect muscle mass as well as fat, the Quetelet Index (wt/ht^2) was chosen as a correlate with blood pressure. This index has been shown to be independent of height (79) and where there are insufficient numbers of subjects to estimate linear regression the Quetelet is probably the best index (80).

As shown in Tables 12 and 13, the Quetelet Index was positively correlated with systolic blood pressure for all age groups, except the youngest age group of both sexes. It was positively correlated with diastolic (4th phase) blood pressure for males in all age groups and for females in all age groups except the youngest (Tables 14 and 15).

Since the Quetelet Index is an index of overweight, the results of the correlations observed might suggest that at younger ages, in this case 5 - 6 years of age, there is little overweight. However, in the older age group the indication is that although height increases with age, weight increases in greater proportion. The observation that the risk of hypertension in previously normotensive persons was proportional to the degree of overweight (81) might suggest that these subjects need to be followed up in order to determine how changes in body weight and body height might affect their blood pressure levels.

d) Triceps Skinfold Thickness

Triceps skinfold, which is an indication of the quantity of extremity fat (82) was higher for males than females in the 5 - 6, 9 - 10, and 11 - 12 year age groups. In all the other age groups, females had higher triceps skinfold thickness. Thus, the degree of fatness observed

through triceps skinfold measurements was higher for females in most age groups. Females in the 13 - 14, 15 - 16 and 17 - 18 year age groups had much higher skinfold measurements than males in similar age groups (Tables 10 and 11). In another study by Miller and Shekelle (63) females in the 15 - 16 year age group were also reported to have higher skinfold measurements than males. This would tend to indicate that during the adolescent years, females accumulate more fat than males. These results are comparable with those obtained in the United States (83, 84).

(i) Correlation Between Triceps Skinfold Thickness and Blood Pressure

Triceps skinfold was better correlated with diastolic (4th phase) blood pressure than systolic blood pressure. There were positive correlations in all age and sex groups for diastolic (4th phase) blood pressure (Table 14 and 15); however, in the case of systolic blood pressure there were more negative than positive correlations among the the female age groups (Table 13). Negative correlations were also obtained for two male age groups (Table 12).

With regards to studies of children and adolescents, Stine *et al* (62) also found positive correlations between systolic and diastolic blood pressure respectively, in children 7 - 12 years of age. Correlation of the same sign were found for adolescents 15 - 16 years of age by Miller and Shekelle (63).

The Goteborg study (85) has demonstrated a clear correlation of skinfold thickness not only with blood pressure but also with the prevalence of hypertensive retinopathy.

e) Subscapular Skinfold Thickness

There were slight differences between the sexes in the mean subscapular skinfold measurements obtained for the 5 - 6, 7 - 8, 9 - 10 and 11 - 12 year age groups. In the latter age groups, males in the 5 - 6 and 11 - 12 year age groups had higher readings. However, the differences were greater for the 13 - 14, 15 - 16 and 17 - 18 year age groups where females had higher mean subscapular skinfold measurements (Tables 10 and 11). In a study of American children (83, 84) it was reported that girls 6 to 17 years of age had higher mean subscapular skinfolds than boys.

The difference in results between these two studies for girls in the 11 - 12 year age group could be due to the fact that girls in this study were not as fat as those measured in the American study. Another reason is that these differences might be due to error made in measuring the subscapular skinfold in this age group.

Since the subscapular skinfold estimates the fat on the trunk (86) it would be reasonable to suggest that males in this study belonging to the 5 - 6 and 11 - 12 year age groups had more fat on the trunk than females. Thus the difference between the results of this study and the American study (83).

(i) Correlation Between Subscapular Skinfold Thickness and Blood Pressure

Subscapular skinfold was better correlated with blood pressure in females than males. All female age groups showed positive correlations between subscapular skinfold thickness and diastolic (4th phase) blood pressure (Table 15). The correlation of this variable with systolic blood pressure was positive also for female age groups except

the 5 - 6 year age group (Table 13).

Fewer positive correlations between subscapular skinfold and blood pressure were observed among the male age groups. For systolic and diastolic (4th phase) blood pressures, respectively, 5 of the 7 male age groups showed positive correlation with subscapular skinfold (Table 12 and 14).

From these results it does appear as if blood pressure and subscapular skinfold are better correlated among females than males. The subscapular skinfold which estimates the fat on the trunk (86) would be expected to show this relationship for females since during childhood girls are somewhat fatter than boys. This difference becomes more noticeable in girls during adolescence. This gradual increase in body fat deposition occurs in both boys and girls during late childhood and early adolescence (87). However, in girls this deposition of fat accelerates to the sixteenth or seventeenth year of life when there is a slackening in normal fat deposits (88). Boys show an opposite picture of fat deposition during adolescence. They have instead a tendency towards leaness during this period of growth and sexual maturation and their body fat actually decreases to the lowest levels in the late teens (89, 90).

f) Upper Arm Circumference

Upper arm circumference increased with age for both sexes. However, there were no consistent differences in upper arm circumference between the same age groups of the two sexes.

(i) Correlation Between Upper Arm Circumference and Blood Pressure

All age groups, except one from each sex, had positive

correlations between upper arm circumference and systolic blood pressure (Tables 12 and 13). Upper arm circumference was positively correlated with diastolic (4th phase) blood pressure in all female age groups, however, positive correlations between these two variables were obtained in only 5 of the 7 male age groups.

These results seem to indicate that upper arm circumference is best correlated with diastolic (4th phase) blood pressure among females aged 5 - 18 years of age. However, evidence about the relationship between upper arm circumference and blood pressure remains inconclusive and confusing. In one study (15) in which direct measurement of arterial pressure was taken in one arm by the intra-arterial method of Hamilton, and indirect measurement made simultaneously in the other arm by a standard mercury sphygmomanometer, there was a tendency for indirect readings to be lower than intra-arterial readings for subjects with thin arms and higher for subjects with thick arms. Another study (19) failed to demonstrate any relationship between arm circumference and the difference between simultaneously taken direct and indirect measurements of arterial pressure. The question of whether the thickness of the arm does result in errors in the recordings of blood pressure has been discussed by Evans and Rose (91) who concluded that the error is probably small.

In this study this kind of error is unlikely since a full size adult cuff, which adequately encircled the arm, was used in all cases.

g) Resting Heart Rate (beats/min)

The mean resting heart rate was higher for females than

males in most age groups (Tables 16 and 17). A possible explanation for this finding could be that some of the females in this study were more emotionally aroused by the surroundings in which they found themselves.

(i) Correlation Between Resting Heart Rate and Blood Pressure

All age groups except one from each sex showed positive correlations between resting heart rate and systolic blood pressure (Table 18). Positive correlations were obtained between resting heart rate and diastolic (4th phase) blood pressure in all age groups of both sexes (Table 19).

Miller and Shekelle (63) in their study of subjects 15 to 16 years of age also found that resting heart rate was positively correlated with both systolic and diastolic blood pressure.

The observed positive correlations between resting heart rate and blood pressure are important. It has been observed that young persons with borderline hypertension have a hyperkinetic circulation where the increased cardiac output seems to be due to an increased heart rate (92). Although the mechanism by which this observation can be explained is not clearly understood, Ellis and Julius (93) suggest that the autonomic nervous system is responsible for the rise in cardiac output, heart rate and stroke volume in these subjects.

Increased heart rate has been discussed as a predictor for developing hypertension (94).

h) Amplitude of P Wave in Lead II

The mean amplitude of the P wave in lead II was the same for each corresponding age group of both sexes (Tables 16 and 17).

(i) Correlation Between Amplitude of P Wave in Lead II and Blood Pressure

Positive correlations between amplitude of P wave in lead II and systolic and diastolic (4th phase) blood pressures respectively were obtained for all age groups of both sexes (Tables 18 and 19). This study is presumably the first to investigate the correlation between amplitude of P wave and blood pressure. It would therefore require further investigations in order to find out whether this finding is reproducible. In the meantime it would be relevant to mention that the amplitude of the P wave is helpful in the evaluation of atrial enlargement (95).

j) Amplitude of R Wave in Lead II

The amplitude of the R wave in lead II was higher in males belonging to the 7 - 8, 13 - 14 and 15 - 16 year age groups than females of corresponding age groups (Tables 16 and 17). Females in the other age groups: 5 - 6, 9 - 10, 11 - 12 and 17 - 18, had higher amplitude of R wave.

These differences in amplitude could have been due to such factors as the distance of the heart from the recording electrode as determined by the size of the chest, thickness of the chest wall, and the presence of emphysema, etc. (96).

(i) Correlation Between Amplitude of R Wave in Lead II and Blood Pressure

Positive correlations between the amplitude of R wave in lead II and blood pressure were obtained for all age groups of both sexes (Tables 18 and 19). This finding is also new and would therefore

require other studies to confirm or deny its validity. However, it should be pointed out that the amplitude of the R wave is related to the mass of the ventricular tissue (97). One may speculate that in this group of subjects there is an increase in the mass of ventricular tissue.

k) Family Size and Birth Order

(i) Correlation Between Family Size and Blood Pressure

Family size was positively correlated with the systolic blood pressure of males and females of most age groups (Table 20). In the case of diastolic (4th phase) blood pressure most male age groups showed negative correlations, whereas more positive correlations were obtained for the female age groups (Table 21).

In a study (98) which looked at family size and blood pressure levels of parents it was found that married women without children had higher levels of blood pressure than those with one child. The indication was that the larger the family the lower was the blood pressure of the mother. The same finding was reported for the systolic blood pressure of men. The same was not true for diastolic blood pressure.

This observed association between family size and blood pressure levels in this age group, especially systolic blood pressure levels, is an interesting one which needs to be investigated to find out whether children belonging to larger families tend to have lower blood pressure levels or vice versa.

(ii) Correlation Between Birth Order and Blood Pressure

Male age groups showed more positive correlations between

birth order and systolic blood pressure than female age groups (Table 20). In the case of diastolic (4th phase) blood pressure there were more female than male age groups with positive correlations (Table 21).

Paffenbarger (57) found that first born children had a significantly higher incidence rate of eventual hypertension than students who were later born.

In view of the findings of this study and that of Paffenbarger's, an analysis of the data is being done to investigate whether first born children in this study have higher blood pressure levels than those who were lower in the birth order.

This would aid in the identification of potential hypertensives.

Determinants of Blood Pressure Levels Obtained Through Multiple Linear Regression Analysis

a) Introduction

Although it has often been stated that primary hypertension is a disease of multifactorial etiology, few attempts have been made in studies of children and adolescents to evaluate the relationship of multiple factors of possible pathogenic significance to blood pressure.

In this analysis, blood pressure was considered as the dependent variable, this is, the end point. The purpose of this analysis was to elucidate factors which may be playing a role in the pathogenesis of primary hypertension.

b) Resting Heart Rate and Amplitude of P Wave in Lead II

The findings of this study shown in Tables 26, 27, 28 and

29, indicate that the two variables - resting heart rate and amplitude of P wave in lead II - were independently related to both systolic and diastolic (4th phase) blood pressure in both the 5 - 12 and 13 - 18 year age group. The p value for resting heart rate was <0.001 for systolic and diastolic (4th phase) blood pressure in both age groups. For amplitude of P wave in lead II, the p value was <0.001 for systolic blood pressure in the 5 - 12 and 13 - 18 year age group, and <0.01 and <0.05 for diastolic (4th phase) blood pressure in the 5 - 12 and 13 - 18 year age groups, respectively.

These findings suggest that resting heart rate and amplitude of P wave in lead II can be used as predictors of the level of systolic and diastolic (4th phase) blood pressures in children and adolescents 5 - 18 years of age.

(i) Resting Heart Rate

The belief that higher resting heart rate may either play a role in the pathogenesis of hypertensive disease or be an index of some other pathogenic factor, has received substantial support from other studies. The results of three longitudinal studies showed that elevated heart rate was a predictor of hypertension in later life (99, 72, 100). Two other studies, one of white males (101) and the other of blacks (102) found that heart rate levels correlated with blood pressure. Berkson *et al* (103) found that resting heart rate may be an independent risk factor in the genesis of premature clinical coronary heart disease.

From a theoretical point of view the resting heart rate

represents the rate that is necessary for the systolic ejection of the blood in the left ventricle into the aorta and its largest branches. An increase in heart rate might therefore be due to an increased stroke output of the heart or to decreasing distensibility of the great vessels. Since there is no evidence to suggest that stroke output increases with age, the only other possible explanation for increased resting heart rate would be a decrease in distensibility of the great vessels. It has been shown by Bramwell, Downing and Hill (104) that as blood pressure rises, large arteries become less distensible.

This decrease in distensibility of the arteries, which might be due to the alteration of the contractile properties of the smooth muscle in the arteriolar wall (105) results in increased peripheral resistance.

Because of this increased peripheral resistance the ventricle is unable to empty completely during systole. As a result the volume of blood which is left over combines with the blood which flows from the atrium into the ventricle during the next diastole, which causes, once more, an increase in the volume of blood filling the ventricle during diastole.

This causes an added strain on the heart which it copes with by working more economically. However, the heart cannot keep this up indefinitely. A point is reached when the strain exceeds a certain critical level causing the heart muscle to decrease in mechanical efficiency. The oxygen requirement becomes steadily greater, more and more blood accumulates in the ventricle owing to incomplete systolic emptying, and the ventricles begin to dilate. At this stage

the heart is unable to maintain the required output simply by stepping up its stroke volume and, instead, it now has to beat faster and becomes increasingly dependent on stimuli provided by the sympathetic nervous system.

At the beginning this process can be delayed by a compensatory increase in the muscle mass of the myocardium, however, once the weight of the heart exceeds the threshold level of approximately 500 G, its reserves become fully exhausted. The ventricles dilate as a rapid pace, while at the same time the performance of the heart continues to deteriorate. After a while the atria are no longer able to cope with the volume of inflowing blood, with the result that the blood pressure in the veins rises (106).

The findings in this study that elevated resting heart rate is related to higher blood pressure level (Tables 27, 28, 29, 30) might suggest that an increase in resting heart rate is probably an indicator of a predisposition toward hypertensive disease or may play a role in its pathogenesis.

At present further investigation is being carried out into the relationship between heart rate and blood pressure levels observed in these subjects. Preliminary results (not reported in this study) show that those subjects with blood pressure levels ≥ 1 SDU above the mean of their age and sex group have a much higher heart rate than those with blood pressure levels <1 SDU above the mean of their age and sex group.

It is possible that apart from a decrease in the distensibility of the arteries which might lead to increased heart

rate resulting in higher blood pressure levels there might be an abnormal regulation of the autonomic nervous system. This finding has been reported in patients with borderline hypertension (107). Whether neurogenic factors are responsible for the observation of an elevated heart rate with a concomitant increase in blood pressure levels in these subjects will require further studies.

(ii) Amplitude of P Wave in Lead II

The finding that the amplitude of the P wave in lead II was a significant determinant of systolic and diastolic (4th phase) blood pressures in children and adolescents 5 - 18 years of age is new. A possible explanation for this finding could be that the height of the P wave, which represents atrial depolarization, might be related to the mass of the atrial tissue.

Since the amplitude of the R wave in the QRS complex is much higher than that of the P wave, because the mass of ventricular tissue is greater than that of the mass of the atrial tissue (97), it would seem reasonable to postulate that the increase in the amplitude of the P wave in lead II leads to an increase in blood pressure levels because of an increase in the mass of the atrial tissue.

c) Amplitude of R Wave in Lead II

The amplitude of R wave in lead II was independently related to systolic blood pressure ($p < 0.001$) in both the 5 - 12 and 13 - 18 year age groups. This finding which is also new would suggest that the amplitude of the R wave in lead II is predictive of the level of systolic blood pressure in 5 - 18 year olds.

The R wave is a part of the QRS complex that is caused by

excitation of the ventricles thus leading to ventricular contraction. At the point where ventricular pressure exceeds arterial pressure, the valves of the arteries are opened and blood is rapidly ejected from the ventricles. The right ventricle must achieve a pressure of only 18 mmHg to open the pulmonary valve; the left ventricle must create about 80 mmHg pressure to open the aortic valve. The thicker wall of the left ventricle renders the ventricle capable of generating this higher pressure which is reflected in the amplitude of the R wave. Thus an increase in amplitude of the R wave would indicate that there is an increase in the mass of the ventricles which would lead to stronger contraction and greater emptying of blood at higher pressures.

d) Family Size

Family size was found to be a positive significant determinant of both systolic ($p < 0.05$) and diastolic ($p < 0.001$) (4th phase) blood pressure in the 5 - 12 year age group. This finding was not duplicated in the 13 - 18 year age group.

A tentative interpretation of this finding would be that the blood pressure levels of younger subjects are influenced by the size of the family, in that younger subjects who are members of larger familiies will tend to have higher blood pressure levels. However, it does appear as if this influence if lost when the subject enters the adolescent period. It could be hypothesised that older subjects (13 - 18 years of age) are more independent of the family unit and so are likely to be less subjected to stressful experiences as a result of parental constraints.

On the other hand, younger subjects are more restricted by parental control and living in larger families might add to their

problems of coping, thus leading to higher levels of blood pressure.

e) Height

Height was found to be a positive significant determinant of systolic blood pressure ($p < 0.001$) in the 5 - 14 year age groups. This finding corroborates that of Voors *et al* (13). These researchers found that height had a strong significant influence on the systolic blood pressure measurements of children 5 - 14 years of age which were taken with a Physiometrics Automatic Blood Pressure Recorder. They also found that this variable significantly influenced diastolic (4th phase) blood pressure as well, however, the results of this study failed to duplicate this finding.

f) Subscapular Skinfold

Subscapular skinfold was found to have a positive significant influence ($p < 0.005$) on diastolic (4th phase) blood pressure in the 13 - 18 year age group.

This finding indicates that subscapular skinfold thickness can be used as a predictor of diastolic (4th phase) blood pressure for those 13 - 18 years of age but not for those in the younger (5 - 12) year age group.

As this time it is difficult to explain this predictable relationship between subscapular skinfold thickness and diastolic (4th phase) blood pressure. However, it is documented that there is a gradual increase in the deposits of body fat in both boys and girls during late childhood and early adolescence.

<u>An Overview of the Determinants of Blood Pressure Levels in the 5 - 12 and 13 - 18 Year Age Groups</u>

It is apparent from Tables 27 and 28 that there are certain

factors: resting heart rate, amplitude of P wave in lead II, and amplitude of R wave in lead II, which have a positive significant influence on systolic blood pressure in both the 5 - 12 and 13 - 18 year age groups, while the influence of height and family size on systolic blood pressure level is only found in the 5 - 12 year age group.

These findings suggest that at younger ages there are more factors operating which might result in an elevation of systolic blood pressure. However, of more importance is the finding that resting heart rate, amplitude of P wave in lead II and amplitude of R wave in lead II are all influencing the level of systolic blood pressure from 5 to 18 years of age.

Tables 29 and 30 show that the level of diastolic (4th phase) blood pressure in the 5 - 12 year age group is significantly determined by three factors. These are family size, resting heart rate and amplitude of P wave in lead II. In the 13 - 18 year age group, resting heart rate, amplitude of P wave in lead II and subscapular skinfold thickness were found to be the factors which significantly determin diastolic (4th phase) blood pressure.

These findings show that resting heart and amplitude of P wave in lead II operate as determinants of diastolic (4th phase) blood pressure from 5 to 18 years of age, while family size and subscapular skinfold thickness are determinants in the 5 - 12 and 13 - 18 year age group respectively.

The finding that family size is a significant determinant of both systolic and diastolic (4th phase) blood pressure in the 5 - 12 year age group is an interesting one and it would be worthwhile to investigate in future

studies whether in this population the finding of Miall (98) that parents with more children have lower levels of blood pressure can be replicated.

Of major importance in the finding that resting heart rate and amplitude of P wave in lead II are significant positive determinants of systolic and diastolic (4th phase) blood pressure for both age groups. This would seem to indicate that resting heart rate and amplitude of P wave in lead II can be used as practical criteria for evaluating abnormal blood pressure levels in children and adolescents 5 to 18 years of age.

The fact that resting heart rate, amplitude of P wave in lead II and amplitude of R wave in lead II appear to be playing an important role in determining systolic blood pressure levels in the 5 - 12 and 13 - 18 year age groups might lead one to speculate that these subjects are experiencing a thickening of the arteriolar muscle which will eventually lead to increased peripheral resistence culminating with chronic hypertension together with left ventricular hypertrophy.

Another idea is that the elevated blood pressures observed might be triggered by intermittent bouts of hypothalmic neurohumoral stimulation which causes the cardiac output to increase in genetically susceptible individuals.

Whether or not there are structural changes occuring in the heart and resistance vessels of these subjects with abnormal blood pressure levels that are indicative of the initial phase of hypertension will require further follow-up.

CHAPTER 7

SUMMARY AND CONCLUSIONS

In the Spring of 1975 and 1977, blood pressure measurements of children and adolescents attending school in a rural Newfoundland community were made, using Automatic Blood Pressure Instruments. Three-hundred and twenty participants aged 5 - 18 years of age took part in the 1977 study, 68 of whom had had their blood pressure measured in 1975. This information was used to study the "tracking" of blood pressure in these subjects.

Data obtained in the 1977 study were analysed to ascertain the prevalence of hypertension, the familial aggregation of blood pressure, and the factors associated with, and predictors of, blood pressure levels in these 320 children and adolescents 5 - 18 years of age.

PREVALENCE OF HYPERTENSION

1. The prevalence of systolic hypertension was 1.6%. The prevalence of diastolic (4th phase) hypertension was also 1.6%.

The criteria used to indicate hypertension was blood pressure scores ≥ 2 SDU above the mean of a particular age and sex group.

2. "High Normal" systolic blood pressure was recorded in 14.4% of the subjects and 15.3% had "high normal" diastolic (4th phase) blood pressure.

The criteria used to indicate "high normal" blood pressure was blood pressure scores ≥ 1 to <2 SDU above the mean of a given age and sex group.

FAMILIAL AGGREGATION OF BLOOD PRESSURE

1. Using the technique of ANOVA it was shown that a significant clustering or aggregation of systolic ($p < 0.01$) and diastolic (4th phase) ($p < 0.01$) blood pressure existed within families for subjects 5 - 18 years of age.

"TRACKING" OF BLOOD PRESSURE

1. A highly significant (p 0.0002) "tracking" effect was obtained for systolic blood pressure taken two years apart. It was found that of seven subjects with initial systolic scores greater than 1.0 SDU above the mean, five (71%) had positive SDU scores at follow-up. Of nine subjects with initial systolic scores less than 1.0 SDU below the mean, seven (78%) had negative follow-up scores.
2. A significant (p 0.05) "tracking" effect was obtained for diastolic (4th phase) blood pressure taken two years apart. Of eight subjects with initial scores greater than 1.0 SDU above the mean, seven (88%) had positive scores at follow-up. Of thirteen with initial scores less than 1.0 SDU below the mean, 9 (68%) had negative scores at follow-up.

FACTORS ASSOCIATED WITH BLOOD PRESSURE LEVELS IN CHILDREN AND ADOLESCENTS 5 - 18 YEARS OF AGE

a) Sex and Age

The general tendency was for mean systolic blood pressure to be higher in males than females. For diastolic (4th phase) blood pressure the trend was inconsistent. Males in the 7 - 8, 9 - 10, 11 - 12, and 17 - 18 year age groups had higher pressures than females.

On the other hand, females in the 5 - 6, 13 - 14 and 15 - 16 year age groups had higher diastolic (4th phase) blood pressures.

Systolic blood pressure increased with age for both males and females, however, the increase was more consistent for females. Similar results were obtained for diastolic (4th phase) blood pressure.

Correlation analysis was done between blood pressure and eleven variables for the following male and female age groups: 5 - 6, 7 - 8, 9 - 10, 11 - 12, 13 - 14, 15 - 16 and 17 - 18. The eleven variables correlated with blood pressure were: Height, Weight, Quetelet Index, Triceps Skinfold Thickness, Subscapular Skinfold Thickness, Upper Arm Circumference, Resting Heart Rate, Amplitude of P wave in lead II, Amplitude of R wave in lead II, Family Size and Birth Order.

b) Factors Associated With Systolic Blood Pressure

The results of the correlation analysis showed that:

1. Systolic blood pressure was positvely correlated with Amplitude of P wave in lead II and Amplitude of R wave in lead II for all age groups of each sex.

2. Systolic blood pressure was positively correlated with height, weight, Quetelet Index, upper arm circumference and heart rate in 6 of the 7 age groups of each sex.

3. Triceps Skinfold, subscapular skinfold, and family size were positively correlated with systolic blood pressure in 5 of the 7 age groups of each sex.

4. Birth Order was positively correlated with systolic blood pressure in 5 of the 7 male age groups, and positively correlated in 4 of the 7 female age groups.

c) Factors Associated With Diastolic (4th Phase) Blood Pressure

1. Diastolic (4th phase) blood pressure was positively correlated with height, triceps skinfold thickness, heart rate, amplitude of P wave and amplitude of R wave in all age groups of each sex.

2. Weight was positively correlated with diastolic (4th phase) blood pressure for all female age groups. Positive correlations between these two variables were obtained in 6 of the 7 male age groups.

3. Quetelet Index was positively correlated with diastolic (4th phase) blood pressure for all male age groups. For females positive correlations were obtained for 6 of the 7 age groups.

4. Subscapular skinfold and upper arm circumference were positively correlated with diastolic (4th phase) blood pressure in all of the female age groups and in 5 of the 7 male age groups.

5. Family size was positively correlated with diastolic (4th phase) blood pressure in 5 of the 7 female age groups and in 2 of the 7 male age groups.

6. Birth order was positively correlated with diastolic (4th phase) blood pressure in 4 of the 7 female age groups and in 2 of the 7 male age groups.

PREDICTORS OF BLOOD PRESSURE LEVELS OBTAINED THROUGH MULTIPLE LINEAR REGRESSION ANALYSIS

Multiple Linear Regression Analysis was carried out to ascertain which of the eleven variables, namely, height, weight, Quetelet Index, triceps skinfold thickness, subscapular skinfold thickness, upper arm circumference, resting heart rate, amplitude of P wave in lead II and amplitude of R wave in lead II, family size

and birth order, might be predictive of systolic and diastolic (4th phase) blood pressure in the 5 - 12 and 13 - 18 year age groups. Of these eleven variables the following were found to be significant positive predictors of systolic and diastolic (4th phase) blood pressure (Tables 26, 27, 28, 29).

1. It was found that resting heart rate and amplitude of P wave in lead II were significant positive predictors of both systolic and diastolic (4th phase) blood pressures in the 5 - 12 and 13 - 18 year age groups.
2. Amplitude of R wave in lead II was a significant positive predictor of systolic blood pressure in the 5 - 12 and 13 - 18 year age groups.
3. Family size was a significant positive predictor of systolic and diastolic (4th phase) blood pressure in the 5 - 12 year age group.
4. Height was a significant positive predictor of systolic blood pressure in the 5 - 12 year age group.
5. Subscapular skinfold was a significant positive predictor of diastolic (4th phase) blood pressure in the 13 - 18 year age group.
6. Triceps skinfold and birth order were significant negative predictors of systolic and diastolic (4th phase) blood pressure respectively in the 5 - 12 year age group.
7. Family size was a significant negative predictor of diastolic (4th phase) blood pressure in the 13 - 18 year age group.

In conclusion, it can be said that this study has shown a complex interrelationship between a number of factors and blood pressure levels observed in children and adolescents 5 - 18 years of age. Some of these factors may be causally associated with the

observed blood pressure levels, while others may be demonstrating a statistical association due to confounding factors. Clarification of this will require further investigation.

Some of the findings reported in this study are, to the author's knowledge, new and have never been reported before. However, of primary interest is the fact that increased electromotory force was detected in the electrodardiograms of those subjects with elevated blood pressure levels. While further investigations will be needed to elucidate the nature of this finding one is tempted to speculate that in these subjects as increase in the ventricular muscle mass may be related to an increase in the cardiac stroke volume.

Further speculation may lead one to think that these subjects are in the earliest phase of hypertension which is characterised by increased cardiac output and normal peripheral resistence. One may also suggest that these subjects are experiencing an expanded extracellular fluid volume which may be the immediate cause of the increased cardiac output.

These ideas may be worth investigating in future studies.

This study has also provided evidence to support the phenomenon of "tracking" of blood pressure and by so doing has helped to erase whatever doubts there might be with regards to the usefullness of the method. The familial aggregation of blood pressure was also demonstrated in this study.

Perhaps it would be reasonable to suggest at this point that guidelines are needed which will stipulate the methodology to be used when measuring blood pressure levels in children and adolescents.

These guidelines should include the number of blood pressure measurements to be taken, the posture of the subject, the time that should elapse between measurements. This would facilitate the comparison of results among studies.

At present more studies, preferably longitudinal studies, are required to investigate those factors that might lead to the development of hypertension in later life. The idea of studying blood pressure levels in children is justifiable since it would be more beneficial to conduct such studies as close to the time of onset of hypertension as possible. It is reasonable to assume also that early identification of hypertensives will be most effective in the earliest stages of the disease rather than in the later stages, when tissue changes that are perhaps irreversible may have already occurred.

PLANS FOR FUTURE ACTION

1. Further studies are in progress at the present time to find out whether those subjects who have been identified as hypertensives, and as having "high normal" blood pressure levels belong to families where one or both parents are hypertensives. This would indicate whether or not these subjects have a higher risk of becoming hypertensive later in life.

2. Because it is very important to find out how blood pressure levels change, as well as what factors are responsible for these changes as subjects approach adulthood, this cohort of subjects will be followed longitudinally.

3. Steps will be taken to start an educational program in these schools that would create an awareness of primary hypertension and

its complications. Preventive measures which can be taken to decrease the risk of hypertension will be discussed. Among these are weight reduction, better eating habits, regular exercise, etc.

4. Those subjects with blood pressure levels ≥ 1 to <2 and ≥ 2 SDU above the mean of their age and sex group will be re-measured. Those who remain in the ≥ 1 to <2 SDU category will be closely followed. Anyone who remains in the ≥ 2 SDU category will be referred to a physician for a physical examination in order to find out whether or not the observed blood pressure level is due to a secondary cause.

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APPENDIX A

LETTER SENT BY SCHOOL PRINCIPAL

May 12, 1977

Dear Parent,

This is to inform you that a team from the Faculty of Medicine of Memorial University will be carrying out a BLOOD PRESSURE SURVEY of children attending Tricon Elementary and St. Joseph's High School, beginning May 25, 1977.

The purpose of this survey is to find out the blood pressure of your child. If you do not wish to have your child examined, please let me know. If I do not hear from you, I will assume that you agree to have your child examined.

Thank you.

Sincerely yours,

Principal

APPENDIX B

QUESTIONNAIRE (1975)

HYPERTENSION STUDY — JUNE 1975

BAY DE VERDE SCHOOL CHILDREN

CHILD HISTORY

GRADE:

1. Name _____
2. Sex ☐ Male ☐ Female
3. Identification Number _____
4. Birth Place _____
5. Mother's Name _____
6. Father's Name _____
7. Twin ☐ Yes ☐ No

PHYSICAL EXAMINATION

8. Body Weight _____kgs
9. Body Height _____cm
10. Upper Arm Circumference _____cm
11. Blood Pressure Measurements (seated):

    (a) Systolic Blood Pressure 1. _____ 2. _____

    (b) Diastolic (4th phase) Blood Pressure 1. _____ 2. _____

APPENDIX C

QUESTIONNAIRE (1977)

HYPERTENSION SURVEY – MAY/JUNE 1977

BAY DE VERDE SCHOOL CHILDREN

CHILD HISTORY

GRADE:

1. Child's Name _____
2. Sex ☐ Male ☐ Female
3. Identification Number _____
4. Date of Birth ☐☐ Day ☐☐ Month ☐☐☐☐ Year
5. Place of Birth _____
6. Twin ☐ Yes ☐ No
7. Telephone Number _____
8. Mother's Name _____
9. Mother's Date of Birth ☐☐ Day ☐☐ Month ☐☐☐☐ Year
10. Father's Name _____
11. Father's Date of Birth ☐☐ Day ☐☐ Month ☐☐☐☐ Year
12. Size of Nuclear Family _____
13. Number of Brothers _____
14. Number of Sisters _____
15. Order of Birth 1 : 2 : 3 : 4 : 5 : 6 : 7 : 8 : 9 : 10 : 11 : 12
16. Number of Older Brothers _____
17. Number of Older Sisters _____
18. Number of Younger Brothers _____
19. Number of Younger Sisters _____

PHYSICAL EXAMINATION

20. Height _____cm
21. Weight _____kgs
22. Skinfolds (mm): (a) Triceps 1. _____ 2. _____
    (b) Subscapular 1. _____ 2. _____
23. Upper Arm Circumference (cm) 1. _____
    2. _____

BLOOD PRESSURE SEATED

24. Systolic 1. _____ 2. _____
25. Diastolic (4th phase) 1. _____ 2. _____
26. Heart Rate / Min _____

REMARKS:

APPENDIX D

INFORMATION REQUESTED FROM PARENTS

CHILD'S Name : GRADE :

Date of Birth :

Birth Order (including deceased offspring):

No. of Older Brothers :

No. of Older Sisters :

No. of Younger Brothers :

No. of Younger Sisters :

Mother's Name :

Date of Birth :

Father's Name :

Date of Birth :

Telephone Number:

APPENDIX E

ANOVA OF SYSTOLIC BLOOD PRESSURE IN SDU FOR 5-12 YEAR AGE GROUP

Analysis of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F Score	p
Regression	11	39.36307	3.57846	4.43672	< 0.001
Residual	164	132.27508	0.80656		

ANOVA OF DIASTOLIC (4th PHASE) BLOOD PRESSURE IN SDU FOR 5-12 YEAR AGE GROUP

Analysis of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F. Score	p
Regression	11	32.14646	2.92241	3.67191	<0.001
Residual	164	130.52449	0.79588		

ANOVA OF SYSTOLIC BLOOD PRESSURE IN SDU FOR 13-18 YEAR AGE GROUP

Analysis of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F. Score	p
Regression	11	24.54280	2.23116	2.66156	<0.01
Residual	122	102.27158	0.83829		

ANOVA OF DIASTOLIC (4th PHASE) BLOOD PRESSURE IN SDU FOR 13-18 YEAR AGE GROUP

Analysis of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F. Score	p
Regression	11	31.25059	2.84096	3.62113	<0.001
Residual	122	95.71525	0.78455		