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Blood Pressure in Atherosclerosis-Susceptible and -Resistant Pigeons (40626)

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White Carneau (WC) pigeons in contrast to Show Racer (SR) pigeons at a similar plasma cholesterol concentration have aortic atherosclerosis that develops naturally even when the animals are fed cholesterol-free grain diets (1, 2). It has been suggested by some authors (3) that blood pressure increases in WC but not in SR pigeons from 9 to 17 months of age may be related to the increased atherosclerosis of the WC pigeon since it is at this age the birds begin to develop aortic plaques. In an attempt to determine a relationship between blood pressure and aortic atherosclerosis, Middleton *et al.* (4) studied 146 8-year-old WC pigeons and concluded no such relationship existed. Because of the usefulness of the WC pigeon in atherosclerosis research, we designed a study to investigate factors effecting blood pressure in this breed and compared these findings with the atherosclerosis-resistant SR pigeon. In this report we provide information to determine any seasonal, age, and sex influence on blood pressure as well as the relationship of blood pressure and diet-induced atherosclerosis of WC pigeons.

Materials and methods. The pigeons used in this study were obtained from the breeding colonies at the Bowman Gray School of Medicine research farm. WC pigeons were derived from a colony of pigeons that were mated and bred randomly; SR pigeons were from lines SR 37 and SR 39 (5) maintained and bred randomly for at least 16 generations. All pigeons were housed in outdoor flypens as described by Clarkson *et al.* (6) and subjected to environmental conditions prevailing in Winston-Salem (described in detail by Nohlgren and Wagner (7)).

Blood pressure measurement. Blood pressure was measured directly from the alar artery of restrained, unanesthetized, hooded pigeons. A physiograph 4 and Model P1000 pressure transducer (E & M Instrument Co., Inc., Houston, Tex.) were used initially. Later studies were done using a Grass Model 5 physiograph (Grass Instrument Co., Quincy, Mass.). The needle of a 23-gauge butterfly infusion set was filled with heparinized saline and inserted into the right alar artery. Mean blood pressures were determined by dampening the pressure transmitted to the transducer in a gradual and complete manner by occluding the cannula with a hemostat. Throughout the study we routinely obtained a continuous tracing of blood pressure for 5 min postcannulation and usually selected the 3-min values to represent the basal blood pressure for an animal.

Seasonal effect on blood pressure. Seasonal influence on blood pressure was determined from monthly observations on 13 WC pigeons ranging in age from 3 to 9 years.

Effect of age, sex, and breed on blood pressure. Eighty WC, 50 SR 37, and 21 SR 39 distributed nearly equally among the ages of 3–5 months, 1, 3, 4, 6, or 8 years were used to evaluate any effects of age, sex, or breed on blood pressure. Housing was as follows: flypen 1, 3–5 month and 8-year-old pigeons; flypen 2, 3- and 6-year-old pigeons; flypen 3, 1- and 4-year-old pigeons. All blood pressure measurements were done during a 19-day period on WC and SR pigeons chosen randomly from each of the pens of animals. Blood pressure was determined on the basis of a single observation for each animal. These measurements were repeated on all animals 6 months later (October) and found to differ by only 6.6, 7.2, and 10.2% for mean, diastolic, and systolic pressures, respectively, for both WC and SR pigeons.

Relationship of blood pressure and aortic atherosclerosis. The association of blood pressure and atherosclerosis was evaluated in 184 WC pigeons of either sex and 18–22 weeks of age. The blood pressure was measured for each animal and then all pigeons were fed an atherogenic diet (Purina pigeon pellets:lard: cholesterol; 89.75/10.0/0.25) for 6 months.

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Blood pressure was determined at the end of 6 months and the animals were killed. The extent and severity of aortic atherosclerosis was determined as described previously (8).

Statistical analysis of data. Statistical significance of data was determined by one or more of the following statistical tests: paired or nonpaired Student's *t* test, analysis of variance, and Duncan's multiple range test or Tukey's HSD.

Results and discussion. Preliminary studies using three WC pigeons indicated very little fluctuation in mean blood pressure from 1 through 30 min postcannulation. The measurements taken during the first several minutes postcannulation appeared to be representative of a basal blood pressure. When 13 WC pigeons were studied, the group had an average mean blood pressure of 155–159 mm Hg with standard deviations of only 3–5 at minute intervals from 1 to 6 min postcannulation.

The variability in blood pressure within and between WC pigeons during a 1-year period is illustrated in Fig. 1. Ranges of 182–194 and 128–141 mm Hg were seen, respectively, for systolic and diastolic measurements. The data in Fig. 1 indicate that the systolic, mean, and diastolic blood pressures showed no consistent fluctuations attributable to the time of the year that the blood pressures were measured. When the blood pressure values of all pigeons were averaged no significant influence of season was seen. However, an impression of lower systolic pressures in the summer months and higher systolic pressures in winter months was obtained. An influence of a seasonal effect on blood pressure has been reported in chickens by Weiss *et al.* (9). Higher systolic pressures in winter and lower pressures in summer months were reported for 219 adult chickens. These seasonal differences were reproducible over several seasonal cycles and approximated a 10% decrease from winter to summer for both sexes. Weiss *et al.* (9) indicated that the lower systolic blood pressures in chickens in warm weather were the results of the ambient temperature and not the amount of light.

It is interesting that even under the influence of our moderate climate, we saw a trend of a seasonal effect. Mean monthly temperatures from June to September when the study was done ranged from 21 to 27°. Apparently cardiovascular mechanisms resulting in reduced blood pressure operate at these temperatures. The effect on blood pressure may result in part from a reduced total peripheral resistance through vasodilation to provide for body temperature regulation through evaporative cooling by panting.

The effect of age and sex on systolic and diastolic blood pressure in WC and SR pigeons is illustrated by Fig. 2. There were no differences in blood pressure of SR 37 and SR 39 pigeons and the data for these two lines of SR pigeons were combined. For WC pigeons, the results of an analysis of variance indicated no significant effect of age on blood pressure. In SR pigeons, no major differences were observed in blood pressure throughout the age range studied. Young SR pigeons appeared to have a higher diastolic pressure than older pigeons. Mean values for 1-year-old pigeons were significantly ($P < 0.05$)

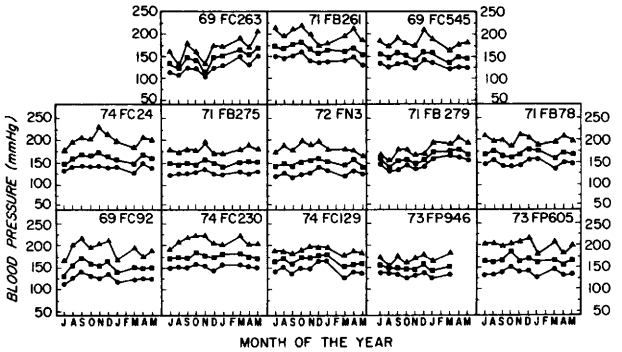

FIG. 1. Systolic (▲), mean (■), and diastolic (●) blood pressures of White Carneau pigeons during a 1-year period. Letters indicate month of the year.

higher than those of 3, 4, and 5 years of age and 3- to 5-month-old pigeons were significantly higher than those of 3 and 4 years of age.

It has been reported that chickens have a significant increase in blood pressure from ages 10–14 months to ages 42–54 months (10). Information on the WC pigeon (3) indicated that the systolic pressure increased from 155 mg/Hg at 9 months of age to 169 mm/Hg at 17 months of age but SR pigeons did not show any age-related increase. In this study, at no age did we see significantly higher blood pressure values in WC compared with SR pigeons. Additionally, our results indicate no influence of the sex of the pigeon on blood pressure of either WC or SR pigeons.

The findings that blood pressure increases are not apparent in WC pigeons from 6 to 12 months of age when naturally occurring atherosclerosis begins and that WC and SR pigeons have similar blood pressure levels indicate that blood pressure increases do not account for the atherosclerosis susceptibility characteristic of the WC pigeon.

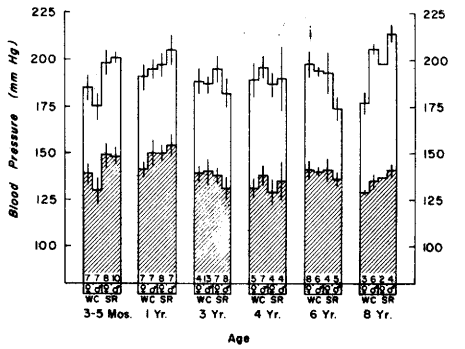

FIG. 2. The effect of age and sex on blood pressure in White Carneau (WC) and Show Racer (SR) pigeons. The lower cross-hatched portion of each bar represents the mean diastolic blood pressure. Upper portion of each bar represents the mean systolic blood pressure. Vertical lines indicate ± SEM. Numbers at the bottom of each bar indicate the number of studied. Significant differences $P < 0.05$, SR 3–5 months > SR 3 and 4 years; SR 1 year > SR 3, 4, and 5 years.

WC pigeons fed an atherogenic diet for 6 months had 4.7 ± 0.19% (mean ± SEM) of the aortic surface covered with raised atherosclerotic plaque. The values for extensiveness of atherosclerosis ranged from 0 to 38% in the group. On the basis of studies of the natural progression of atherosclerosis in the WC pigeon (1) it is probable that no or very little atherosclerosis was present in the 18- to 22-week-old pigeons at the beginning of the study and the aortic plaques were in large part induced by diet. As an estimate of the severity of the diet-induced atherosclerosis, aortic cholesterol concentration, and content were, respectively, 4.48 ± 0.19 mg/g wet aorta and 0.409 ± 0.07 mg/aorta/500 g body wt (mean ± SEM). For comparison, those pigeons without visible atherosclerosis had aortic cholesterol concentrations of 1.36 mg/g and contents of 0.124 mg/aorta/500 g body wt ($n = 28$).

In the entire population of pigeons studied, there were small but significant ($P < 0.01$) increases in mean and diastolic blood presures after the 6-month period that the atherogenic diet was fed (Table I). In an attempt to more clearly evaluate blood pressure changes in pigeons with and without appreciable atherosclerosis, the entire group was subdivided into animals having aortic cholesterol contents either no greater than 0.15 mg or greater than 0.50 mg. These groups represented animals with minimal or no atherosclerosis (1.2% of the aortic surface with plaque) and animals with extensive atherosclerosis (16% of the aortic surface with

TABLE I. BLOOD PRESSURE OF WHITE CARNEAU PIGEONS FED AN ATHEROGENIC DIET FOR 6 MONTHS

Group	mg chol/ aorta/500 g body wt	% Intimal surface with raised atherosclerotic plaque	N	Preexperimental blood pressure (mm Hg)			6-Month blood pressure (mm Hg)		
				Systolic	Mean	Diastolic	Systolic	Mean	Diastolic
All animals	0.409 ± 0.837	4.7 ± 6.7	184	183 ± 13	154 ± 11	137 ± 11	185 ± 18	158 ± 14[a]	141 ± 13[a]
Minimum atherosclerosis	0.129 ± 0.018 (≤0.15)	1.2 ± 2.5	44	182 ± 13	152 ± 11	135 ± 9	177 ± 17	154 ± 9	137 ± 11
Extensive atherosclerosis	1.504 ± 1.860 (≥0.50)	16.0 ± 10.3	23	182 ± 11	153 ± 13	137 ± 9	195 ± 17[a, b]	164 ± 15[a, b]	146 ± 13[a, b]

All values are means ± SD.

[a] Significant differences with groups, $P < 0.01$.

[b] Significant differences between groups with minimum and extensive atherosclerosis, $P < 0.01$.

plaque) (Table I).

Pigeons with extensive atherosclerosis had significantly greater systolic, diastolic, and mean blood pressures in comparison to pigeons with little or no atherosclerosis. Pressures after 6 months were elevated significantly above the preexperimental values only in animals with extensive and severe atherosclerosis. No blood pressure differences were seen in any of the three groups of pigeons at the beginning of the study (Table I). Since the pressure changes were seen only after pigeons had extensive atherosclerosis and were not present in animals with minimal levels of atherosclerosis, the data support the contention that blood pressure increases in WC pigeons are a result of atherosclerosis. Dietary aggravated plaques are more severe than those in naturally occurring atherosclerosis and it is reasonable to assume that this accounts for our findings on the lack of increase of blood pressure with increasing age in the WC pigeon.

Summary. Studies were designed to determine the influence of season, age, sex, and atherosclerosis on blood pressure in the White Carneau (WC) pigeon, a breed that develops naturally occurring atherosclerosis. Comparisons were made with the Show Racer (SR) pigeon, a breed that is resistant to aortic atherosclerosis. In WC pigeons of 3–5 months, 1, 3, 4, 5, or 8 years of age, no influence of age or sex of the pigeon on blood pressure was measured. At no age did we see significantly higher blood pressure levels in WC compared with SR pigeons. WC pigeons, of an age prior to the development of naturally occurring atherosclerosis, were fed an atherogenic diet for 6 months. Only pigeons with extensive atherosclerosis had significantly greater systolic, diastolic, and mean blood pressures. The study provides evidence that blood pressure increases do not account for the atherosclerosis susceptibility of WC pigeons and that extensive and severe atherosclerosis result in elevated blood pressure levels in WC pigeons.

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