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The Relationship between Age and Genotype and Circulating Concentrations of Triiodothyronine (T3), Thyroxine (T4), and Growth Hormone in Commercial Meat Strain Chickens (42349)

M. S. LILBURN,* F. C. LEUNG,† K. NGIAM-RILLING,* AND J. H. SMITH*

**Hubbard Farms Research and Development, Walpole, New Hampshire 03608, and †Department of Animal Physiology, Merck, Sharp & Dohme Research Laboratories, P.O. Box 2000, Rahway, New Jersey 07065*

Abstract. The presence of the sex-linked dwarf gene (*dw*) in homozygous male (*dw/dw*) and female (*dw/−*) meat strain chickens is associated with a significant reduction in circulating levels of triiodothyronine (T3). Heterozygous (*Dw/dw*) male broiler strain chickens have T3 concentrations similar to those in homozygous (*Dw/Dw*) male broilers. Genetically normal (*Dw/Dw*) but significantly slower growing roaster strain male meat chickens had consistently higher T3 than the faster growing broilers at all ages in one experiment but only at 8 weeks in a second experiment. Age and not growth rate appears to have a greater influence on serum T3 concentrations in the slow- and fast-growing normal strains. Growth hormone levels were significantly higher in the dwarf chickens at all ages and in all three experiments. The heterozygous and homozygous broilers had similar GH levels and the slow-growing, genetically normal roasters had intermediate concentrations between the broiler and dwarf lines. GH was influenced to a greater extent by the rate of body weight gain than by increasing age in the genetically normal fast and slow growing strains.

Modern selected strains of broilers demonstrate accelerated growth rates from 0 to 4 weeks of age, especially when compared with those of nonselected, random-bred populations representing the commercial broiler of 20 years ago (1). The endocrine changes that have contributed to and/or evolved from differences in growth rate have only recently been studied. Burke and Marks (2) reported that at equal ages commercial broiler chickens had significantly lower serum growth hormone (GH) concentrations than slow-growing, nonselected lines. May and Marks (3) reported a similar situation for triiodothyronine (T3).

The sex-linked dwarfing gene (*dw*) (4) has been introduced into meat strains of chickens for the purpose of decreasing the cost of rearing broiler breeder parent stock while still allowing for near maximal growth in the broiler progeny. The major phenotypic effects of the *dw* gene are a reduction in body size caused by shortening of major long bones and physiologic effects on protein and lipid metabolism (5, 6) and liver glycogen storage (7).

From an endocrine standpoint, the *dw* gene has associated with it several unique characteristics. Dwarf chicks are generally considered to be hypothyroid and both the thyroid gland and serum thyroid hormone binding proteins have been studied (8, 9). Previous studies have also shown that when the *dw* gene was introduced into slow-growing, random-bred broiler (3) or egg-type leghorn lines (10), the dwarfs had depressed T3 and generally elevated T4 concentrations.

The identification of selected genotypes that have specific growth characteristics and hormone profiles has enhanced our understanding of this area of development. Within the literature, however, the data in certain areas are equivocal. The presence of the *dw* gene in heterozygous (*Dw/dw*) normal male chickens is normally associated with a slight depression in growth rate. In one report, however (11), heterozygous males grew faster than their homozygous counterparts and had significantly higher GH but lower T3. Hoshino *et al.* (12) reported that dwarf leghorn males had similar GH concentrations compared with normal, control males while Scanes *et al.* (10) reported elevated GH in dwarf males only at older ages. Stewart *et al.* (11), however, reported that dwarf, random-bred broiler males had significantly higher GH at all ages studied.

In previous studies (10, 11), the slow-growing random-bred and sex-linked dwarf lines have all had a relatively narrow genetic base. Likewise, the comparisons between the com-

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mercial and random-bred broiler lines (2, 3) did not address obvious differences in growth rate (gain/time) in light of published reports, showing that there are significant age effects on circulating levels of T3 and GH. In the initial experiments reported here, the objective was to compare the thyroid hormone and growth hormone characteristics of commercial normal and dwarf meat strains because of the inconsistent data already in the literature. The last experiment addresses the differences between normal and dwarf strains in rate of gain and the effect this may have on hormone comparisons made at a common age.

Materials and Methods. *Experiment 1.* Male and female chicks from a commercial broiler strain and sex-linked dwarf meat strain were studied. All chicks were sexed at a day of age, banded by sex and strain, and brooded together from 0 to 4 weeks. The dwarf males and females were reared in a separate pen but adjacent to the normal broilers from 4 to 8 weeks. A commercial broiler starter diet (Agway Inc., Syracuse, N.Y.) was fed for the entire length of the experiment.

At 2, 4, 6, and 8 weeks of age, 20 birds per sex and strain were weighed and blood samples were taken via cardiac puncture.

Experiment 2. Male chicks from four distinct genotypes were studied. The genotypes studied were (1) homozygous commercial broilers (F-*Dw*/*Dw*), (2) heterozygous commercial broilers (*Dw*/*dw*), (3) homozygous recessive (*dw*/*dw*) sex-linked dwarfs from a commercial dwarf meat strain, and (4) slow-growing roasters (S-*Dw*/*Dw*).

At 1 day of age, 25 chicks per strain were weighed and bled via decapitation. The remaining chicks were brooded together from 0 to 4 weeks of age. The dwarf and slow-growing roaster chicks were reared in a separate pen but adjacent to the two broiler strains from 4 to 8 weeks. At 2, 4, 6, and 8 weeks, 20 chicks per genotype were weighed and blood was collected via cardiac puncture.

Experiment 3. This experiment studied the independent effects of growth rate and age on serum T3, T4, and growth hormone. Male chicks from the roaster (S-*Dw*/*Dw*), broiler (F-*Dw*/*Dw*), and sex-linked dwarf (*dw*/*dw*) strains used in Experiment 2 were again studied. Serum samples were collected at 1 day and 2, 4, 6, and 8 weeks of age as in Experiment 2. Serum samples were also collected when samples of birds from within each strain weighed approximately 200, 400, 800, 1600, and 2400 g.

Measurements and statistics. The serum samples from each experiment were frozen after each collection period and assayed at the same time to avoid interassay variation within an experiment. Growth hormone concentrations were measured by a homologous radioimmunoassay for chicken GH as described by Leung *et al.* (13) with FLcGH-II used as a standard and for iodination. Serum T3 and T4 concentrations were determined by clasp radioimmunoassay kits (Squibb, Inc., Princeton, N.J.).

In Experiment 1, the male and female data were analyzed separately, and within each experiment, each age was considered to be a complete block. The data were subjected to analysis of variance using the least-squares GLM method of the Statistical Analysis System (14). Significant genotype differences within an age group were further separated by the Student–Newman–Keuls multiple range test. Differences were considered significant at $P < 0.05$.

Results. *Experiment 1.* The male and female dwarf chicks weighed significantly less than the normal chicks at all ages studied. Serum T3 concentrations in the male and female dwarf chicks were likewise significantly lower than in the normal chicks at 2, 4, and 6 weeks of age (Tables I, II). There appeared to be an age-related decline from 2 to 6 weeks in both strains and sexes, but at 8 weeks T3 concentrations were elevated in all cases. Thyroxine (T4) levels were elevated in the dwarf males and females only at 2 weeks but GH was higher at all ages.

Experiment 2. The dwarf males (*dw*/*dw*) had the lowest serum T3 concentrations through 6 weeks of age (Table IV) although the roaster chicks (S-*Dw*/*Dw*) grew the slowest of all four crosses (Table III). The roasters and commercial broilers (F-*Dw*/*Dw*) had similar T3 concentrations at 1 day of age. At 2, 4, and 6 weeks of age, however, serum T3 levels in the roaster chicks were significantly higher than either the homozygous (F-*Dw*/*Dw*) or heterozygous (*Dw*/*dw*) broiler crosses. T3 levels were still numerically higher in the roaster strain at 8 weeks of age. In all lines except the sex-linked dwarfs, serum T3 levels appeared to decline after 4 weeks. The T4 data were

TABLE I. SERUM T3, T4 AND GROWTH HORMONE CONCENTRATIONS IN NORMAL AND SEX-LINKED DWARF MALES: EXPERIMENT 1

Age (weeks)	Strain	Body wt (g)	T3 (ng/100 ml)	T4 (μg/100 ml)	GH (ng/ml)
2	Normal (*Dw/Dw*)	294 ± 8	383.8 ± 31.9 (21)	2.55 ± 0.23 (21)	48.7 ± 14.4 (20)
	Dwarf (*dw/dw*)	195 ± 7*	163.6 ± 11.6* (20)	3.08 ± 0.18 (20)	241.6 ± 52.5* (17)
4	Normal (*Dw/Dw*)	941 ± 27	280.5 ± 19.9 (20)	2.78 ± 0.17 (19)	10.1 ± 1.5 (19)
	Dwarf (*dw/dw*)	640 ± 16*	122.1 ± 9.8* (22)	3.12 ± 0.19 (22)	210.1 ± 41.8* (20)
6	Normal (*Dw/Dw*)	1691 ± 34	205.9 ± 18.4 (21)	1.88 ± 0.09 (20)	6.6 ± 1.1 (19)
	Dwarf (*dw/dw*)	1125 ± 24*	99.9 ± 12.2* (18)	1.67 ± 0.09 (18)	47.0 ± 8.3 (18)
8	Normal (*dw/dw*)	2766 ± 41	206.2 ± 25.4 (11)	2.15 ± 0.08 (11)	1.0 ± 0.7 (4)
	Dwarf (*dw/dw*)	1858 ± 32*	178.8 ± 23.1 (14)	2.20 ± 0.06 (14)	14.3 ± 3.3* (11)

Note. Values are means ± SE. Number of birds is indicated in parentheses.
* $P < 0.05$ as compared with normal birds.

somewhat equivocal as there did not appear to be any clear age or strain relationships (Table V).

The dwarf chicks had significantly elevated serum GH at all ages (Table VI). The roaster (S-*Dw/Dw*) chicks had numerically higher

TABLE II. SERUM T3, T4 AND GROWTH HORMONE CONCENTRATIONS IN NORMAL AND SEX-LINKED DWARF FEMALES: EXPERIMENT 1

Age (weeks)	Strain	Body wt (g)	T3 (ng/100 ml)	T4 (μg/100 ml)	GH (ng/ml)
2	Normal (*Dw/−*)	282 ± 5	346.2 ± 22.1 (20)	2.68 ± 0.13 (20)	— —
	Dwarf (*dw/−*)	192 ± 6*	199.5 ± 18.3* (19)	3.34 ± 0.15* (19)	161.5 ± 50.6 (15)
4	Normal (*Dw/−*)	838 ± 14	309.9 ± 21.6 (19)	3.31 ± 0.18 (19)	7.4 ± 3.0 (19)
	Dwarf (*dw/−*)	551 ± 9*	133.7 ± 8.2* (19)	3.19 ± 0.19 (19)	210.2 ± 41.8* (20)
6	Normal (*Dw/−*)	1450 ± 22	176.5 ± 16.9 (19)	1.79 ± 0.07 (19)	1.7 ± 0.3 (17)
	Dwarf (*dw/−*)	983 ± 15*	118.0 ± 12.0* (20)	1.98 ± 0.10 (20)	38.0 ± 6.2 (20)
8	Normal (*Dw/−*)	2212 ± 36	215.2 ± 22.2 (13)	2.22 ± 0.07 (13)	0.5 ± 0.1 (5)
	Dwarf (*dw/−*)	1503 ± 32*	209.0 ± 16.2 (13)	2.45 ± 0.08 (14)	2.5 ± 1.0* (9)

Note. Values are means ± SE. Number of birds is indicated in parentheses.
* $P < 0.05$ as compared with normal birds.

TABLE III. EFFECTS OF GENOTYPE AND AGE ON BODY WEIGHT IN FOUR GENOTYPES OF COMMERCIAL MEAT CHICKENS: EXPERIMENT 2

Age (weeks)	Strain	Body wt (g)
0	*dw/dw*	37.0 ± 0.5 A
	S-*Dw/Dw*	40.0 ± 0.5 B
	F-*Dw/Dw*	44.0 ± 0.8 C
	Dw/dw	42.0 ± 0.4 C
2	*dw/dw*	192 ± 9 A
	S-*Dw/Dw*	175 ± 4 A
	F-*Dw/Dw*	299 ± 8 B
	Dw/dw	301 ± 18 B
4	*dw/dw*	531 ± 15 B
	S-*Dw/Dw*	461 ± 13 A
	F-*Dw/Dw*	904 ± 14 D
	Dw/dw	804 ± 15 C
6	*dw/dw*	1076 ± 29 B
	S-*Dw/Dw*	961 ± 19 A
	F-*Dw/Dw*	1699 ± 37 D
	Dw/dw	1588 ± 27 C
8	*dw/dw*	1693 ± 73 B
	S-*Dw/Dw*	1511 ± 31 A
	F-*Dw/Dw*	2610 ± 38 D
	Dw/dw	2415 ± 63 C

Note. Values are means ± SE. Values followed by different letters are significantly different, $P < 0.05$.

serum GH compared to the homozygous (F-*Dw/Dw*) broilers at 2, 4, and 6 weeks while the heterozygous broilers (*Dw/dw*) were intermediate between the two genetically normal (*Dw/Dw*) lines. All four genotypes showed a decline in GH with increasing age.

Experiment 3. The data from the chicks bled at the same age support the results from Experiment 2 (Table VII). The sex-linked dwarfs had significantly lower T3 and higher GH concentrations at all ages. There were no consistent thyroid hormone differences between the broiler and roaster genotypes except at 8 weeks when the slow-growing roasters had significantly elevated T3. The roasters had numerically higher GH levels at all ages and the differences were significant at 6 and 8 weeks of age.

At similar body weights, the dwarfs still had lower T3 and higher GH levels than the two normal lines (Table VIII). T4 comparisons were inconsistent, although at 400 and 2400 g the dwarfs had significantly higher concentrations. Increasing body weight had no consistent effect on either T3 or T4 in the broiler and roaster genotypes. These two lines had similar GH concentrations at the same body weight while in all three genotypes, GH decreased linearly with increasing body weight.

Discussion. The presence of the sex-linked dwarfing gene (*dw*) in commercial meat strains of chickens is associated with a significant decrease in serum T3. This supports studies with other, very different sex-linked dwarf lines (3, 10, 11). It demonstrates clearly that this is a particular *dw* trait that is not subject to modification by the background genotype into

TABLE IV. THE ONTOGENY OF SERUM T3 IN FOUR DIFFERENT STRAINS OF CHICKENS: EXPERIMENT 2

Age (weeks)	Serum T3 (μg/100 ml)			
	Dw/dw	S-*Dw/Dw*)	*dw/dw*	F-*Dw/Dw*
(Day) 1	245.3 ± 19.4 A (25)	231.1 ± 8.5 A,B (25)	83.7 ± 3.9 C (24)	203.4 ± 5.6 B (25)
2	161.7 ± 18.2 B (20)	282.7 ± 20.1 A (20)	95.2 ± 9.6 C (19)	162.1 ± 14.3 B (20)
4	215.9 ± 12.8 B (19)	269.9 ± 15.1 A (19)	121.9 ± 6.5 C (18)	227.0 ± 9.7 B (19)
6	68.1 ± 5.3 A (20)	177.4 ± 11.7 B (20)	81.8 ± 6.3 A (20)	79.0 ± 5.7 A (18)
8	147.4 ± 11.2 A (19)	168.6 ± 8.4 A (19)	97.6 ± 4.6 B (20)	116.4 ± 5.7 B (20)

Note. Values are means ± SE. Number of birds is indicated in parentheses. Values followed by different letters are significantly different ($P < 0.05$) in each age group as analyzed by the Student–Newman–Keuls test.

TABLE V. THE ONTOGENY OF SERUM T4 IN FOUR DIFFERENT STRAINS OF CHICKENS: EXPERIMENT 2

Age (weeks)	Serum T4 (μg/100 ml)			
	Dw/dw	S-*Dw/Dw*	*dw/dw*	F-*Dw/Dw*
(Day) 1	2.03 ± 0.07 (24)	1.97 ± 0.06 (23)	2.09 ± 0.13 (19)	1.90 ± 0.08 (25)
2	2.23 ± 0.12 A (20)	1.80 ± 0.06 B (20)	1.97 ± 0.12 AB (19)	1.86 ± 0.08 B (20)
4	2.08 ± 0.10 B (20)	2.11 ± 0.10 B (14)	2.58 ± 0.12 A (18)	1.90 ± 0.07 C (19)
6	1.82 ± 0.14 (19)	1.62 ± 0.07 (19)	2.00 ± 0.13 (19)	1.84 ± 0.09 (17)
8	1.61 ± 0.10 (18)	1.59 ± 0.08 (19)	1.61 ± 0.06 (20)	1.33 ± 0.08 (20)

Note. Values are means ± SE. Number of birds is indicated in parentheses. Values followed by different letters are significantly different ($P < 0.05$) in each age group as analyzed by the Student–Newman–Keuls test.

which it is introduced. The significant decrease in T3 is not the causative factor behind the skeletal dwarfism (15), but it may be contributing to some of the unique metabolic and carcass characteristics associated with the gene (11, 16, 17).

The thyroid hormone profile in heterozygous (*Dw/dw*) chicks appears to be somewhat equivocal. Our data suggest that heterozygous broiler males have normal T3 concentrations with somewhat elevated T4 levels. Stewart *et al.* (11) reported in one study that heterozygous males had significantly elevated T4 while T3 was intermediate between homozygous dwarf (*dw/dw*) and normal (*Dw/Dw*) males. In a different report (18), however, there were no genotype effects on T3 or T4 in homozygous and heterozygous normal chicks. Likewise in these reports, the heterozygous chicks grew at the same rate or faster than the homozygous normal birds. Their results and ours suggest, therefore, that while the effects of the *dw* gene on thyroid hormone levels in homozygous dwarfs is independent of genotype,

TABLE VI. THE ONTOGENY OF SERUM GROWTH HORMONE IN FOUR DIFFERENT STRAINS OF CHICKENS: EXPERIMENT 2

Age (weeks)	Serum GH (ng/ml)			
	Dw/dw	S-*Dw/Dw*	*dw/dw*	F-*Dw/Dw*
(Day) 1	346.2 ± 25.5 B (24)	378.8 ± 30.9 B (24)	1584.8 ± 346.7 A (24)	414.5 ± 35.0 B (25)
2	133.7 ± 12.6 B (20)	149.9 ± 12.8 B (19)	309.5 ± 31.9 A (19)	107.8 ± 5.5 B (20)
4	69.9 ± 8.7 C (19)	108.4 ± 11.2 B (20)	329.6 ± 42.4 A (17)	60.0 ± 6.7 C (19)
6	38.8 ± 4.3 B (20)	41.8 ± 5.3 B (20)	168.1 ± 25.7 A (20)	30.4 ± 2.5 B (18)
8	29.7 ± 2.3 B (19)	27.8 ± 2.7 B (19)	181.0 ± 13.5 A (19)	28.8 ± 2.8 B (20)

Note. Values are means ± SE. Number of birds is indicated in parentheses. Values followed by different letters are significantly different ($P < 0.05$) within each age group as analyzed by the Student–Newman–Keuls test.

TABLE VII. THE EFFECT OF AGE AND GENOTYPE ON ENDOCRINE LEVELS IN COMMERCIAL MEAT STRAINS OF POULTRY: EXPERIMENT 3

Age (weeks)	Strain	GH (ng/ml)	T3 (ng/100 ml)	T4 (μg/100 ml)
(Day) 1	*dw/dw*	187.0 ± 16.8 A	38.5 ± 5.2 A	—
	S-*Dw/Dw*	51.4 ± 5.1 B	178.5 ± 19.5 B	—
	F-*Dw/Dw*	37.2 ± 3.2 B	150.5 ± 7.3 B	—
2	*dw/dw*	60.3 ± 7.2 A	129.3 ± 6.0 A	2.25 ± 0.11 A
	S-*Dw/Dw*	54.3 ± 6.0 AB	267.9 ± 16.1 B	1.62 ± 0.07 B
	F-*Dw/Dw*	42.0 ± 4.3 B	272.2 ± 23.2 B	1.71 ± 0.09 B
4	*dw/dw*	122.8 ± 13.6 A	123.5 ± 5.2 A	2.22 ± 0.08 A
	S-*Dw/Dw*	48.7 ± 6.7 B	314.2 ± 6.6 B	1.90 ± 0.05 B
	F-*Dw/Dw*	36.2 ± 5.1 B	327.5 ± 11.9 B	1.76 ± 0.06 B
6	*dw/dw*	96.4 ± 14.3 A	111.9 ± 4.9 A	1.31 ± 0.05 A
	S-*Dw/Dw*	35.8 ± 5.7 B	282.1 ± 11.5 B	1.33 ± 0.05 A
	F-*Dw/Dw*	14.2 ± 2.0 C	274.1 ± 13.9 B	1.50 ± 0.04 B
8	*dw/dw*	52.6 ± 7.0 A	117.4 ± 3.8 A	1.76 ± 0.09
	S-*Dw/Dw*	8.6 ± 1.1 B	264.8 ± 8.0 B	1.82 ± 0.05
	F-*Dw/Dw*	4.2 ± 1.0 C	162.4 ± 11.5 C	1.74 ± 0.09

Note. Values are means ± SE. Values followed by different letters are significantly different, $P < 0.05$.

there is a moderating effect of genetic background on growth and thyroid hormone levels in heterozygotes.

The slow-growing, genetically normal roaster males (S-*Dw/Dw*) had consistently higher T3 levels compared to the fast-growing (F-*Dw/Dw*) broilers in Experiment 2 and at 8 weeks of age in Experiment 3. May and Marks (3) had similar results with a different strain of slow-growing chickens and it would appear therefore that in normal (*Dw/Dw*) genotypes, rate of gain is strongly interrelated with circulating T3.

At a common body weight, the sex-linked dwarfs still have significantly lower T3. This is further evidence that decreased T3 is a spe-

TABLE VIII. THE INFLUENCE OF GENOTYPE ON ENDOCRINE PARAMETERS MEASURED AT A CONSTANT BODY WEIGHT: EXPERIMENT 3

Strain	Body wt (g)	GH (ng/ml)	T3 (ng/100 ml)	T4 (μg/100 ml)
dw/dw	183 ± 4	156.0 ± 26.0 A	112.3 ± 9.3 A	1.64 ± 0.07
S-*Dw/Dw*	190 ± 3	69.4 ± 8.8 B	216.7 ± 7.7 B	1.55 ± 0.07
F-*Dw/Dw*	194 ± 2	52.5 ± 8.5 B	227.3 ± 12.9 B	1.69 ± 0.10
dw/dw	379 ± 9	111.1 ± 17.0 A	114.7 ± 7.9 A	2.30 ± 0.08 A
S-*Dw/Dw*	386 ± 4	32.4 ± 6.7 B	373.6 ± 12.9 B	1.97 ± 0.07 B
F-*Dw/Dw*	382 ± 4	33.0 ± 4.7 B	274.6 ± 15.1 C	1.84 ± 0.05 B
dw/dw	788 ± 4	90.7 ± 14.9 A	133.9 ± 10.7 A	1.87 ± 0.10
S-*Dw/Dw*	795 ± 4	22.0 ± 5.4 B	247.3 ± 14.5 B	1.85 ± 0.07
F-*Dw/Dw*	795 ± 4	36.3 ± 4.8 B	303.5 ± 16.2 C	1.78 ± 0.05
dw/dw	1551 ± 22	52.9 ± 12.0 A	90.6 ± 9.2 A	1.47 ± 0.14
S-*Dw/Dw*	1525 ± 8	17.6 ± 2.6 B	203.7 ± 7.4 B	1.66 ± 0.04
F-*Dw/Dw*	1545 ± 11	13.7 ± 2.3 B	228.9 ± 14.2 B	1.49 ± 0.09
dw/dw	2352 ± 36	26.7 ± 5.9 A	139.6 ± 3.8 A	2.10 ± 0.05 A
S-*Dw/Dw*	2324 ± 32	5.3 ± 0.9 B	211.9 ± 9.8 B	1.93 ± 0.07 AB
F-*Dw/Dw*	2424 ± 30	4.5 ± 0.1 B	177.5 ± 9.4 C	1.77 ± 0.05 B

Note. Values are means ± SE. Values followed by different letters are significantly different, $P < 0.05$.

cific trait associated with the *dw* gene and not indirectly associated with a decrease in body weight gain. The data from the slow-growing roasters and fast-growing broilers are not as clear, however. Both of these genotypes have peak T3 concentrations at approximately 4 weeks of age, but the broilers show a more rapid decline at 6 and 8 weeks. This age effect may be interacting with the rate of gain when comparisons are made at the same body weight. In Experiment 3, the S-*Dw*/*Dw* roaster males show a peak in T3 at 400 g while the F-*Dw*/*Dw* broilers peak at 800 g. This would correspond to approximately 4 weeks of age within each strain respectively. The rate of decline in T3 with increasing weight gain is faster in the F-*Dw*/*Dw* broilers, similar to the trend seen with advancing age. Age would thus appear to have a greater influence on T3 concentration than would rate of gain.

In all three experiments, the sex-linked dwarfs had significantly elevated GH at all ages and body weights. Stewart *et al.* (11) reported similar results where the *dw* gene had been introduced into a nonselected, random-bred broiler population. Our data are different from theirs, however, in that the heterozygous and homozygous broilers (Experiment 2) have the same GH levels whereas in their report the (*Dw*/*dw*) chicks were intermediate between the dwarf and normal birds. Scanes *et al.* (10) reported higher GH in very young and older dwarf leghorn strain females while the dwarf males had higher GH only at older ages (>12 weeks). Marsh *et al.* (16) and Hoshino *et al.* (12) also reported no differences in serum GH in control and sex-linked dwarf leghorn populations. Unlike T3 therefore, the background genotype into which the *dw* gene is introduced does appear to have a significant effect on circulating GH levels. All the data suggest that there is a significant *dw* gene × genotype × age effect on GH metabolism and this has been reported for other phenotypic effects of *dw* as well (19).

Our GH data could be the result of several factors. Leung *et al.* (20) reported that hepatic GH receptor binding is significantly depressed in the same dwarf strain studied in these experiments. Recent reports (21, 22) have likewise shown evidence for thyroid hormone involvement in the control of circulating GH levels. The genomic DNA for GH from normal and sex-linked dwarf chicks appears to be similar (20), therefore the receptor and thyroid hormone characteristics of the dwarfs may be contributing to the elevated GH levels and increased individual variation within a population.

The higher serum GH concentrations in the slow-growing (S-*Dw*/*Dw*) roaster chicks supports previous comparisons made between nonselected and selected broiler strains (2). In the first two experiments, GH concentrations decreased with age starting at either 1 day of age or at 2 weeks. In Experiment 3, the decline did not begin until after 4 weeks and this is closer to the pattern described by Burke and Marks (2). All three strains had linear decreases in serum GH with each incremental increase in body weight gain. The genetically normal slow- and fast-growing strains had similar GH concentrations at the same body weight whereas the sex-linked dwarfs were still significantly higher. This is similar to the T3 data in that elevated GH would appear to be a specific trait associated with *dw* and not a function of decreased growth. Our data also support the hypothesis that in genetically normal lines (*Dw*/*Dw*), differences in growth rate (gain/time) at younger ages could account for differences in serum GH when strains and experiments are compared at the same age. Developmental changes in the relationship between individual tissues and GH will need to be studied further to better understand the genetic influences on hormones and growth evident from these experiments.

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1. Marks HL. Growth rate and feed intake of selected and non-selected broilers. Growth **43**:80–90, 1979.
2. Burke WH, Marks HL. Growth hormone and prolactin levels in non-selected and selected broiler lines of chickens from hatch to eight weeks of age. Growth **46**:283–295, 1982.
3. May JH, Marks HL. Thyroid activity of selected, non-selected and dwarf broiler lines. Poult Sci **62**:1721–1724, 1983.
4. Hutt FB. Sex-linked dwarfism in the fowl. J Hered **50**:209–222, 1959.
5. Guillaume J. The dwarfing gene *dw*: Its effects on anatomy, physiology, nutrition, management; its application in poultry industry. World's Poult Sci **32**: 285–305, 1976.

6. Touchburn SP, Blum JC. Effects of the genes for dwarfism (*dw*) and naked neck (*Na*) on chick growth and lipid metabolism. Ann Genet Sel Amin **4**(2):311–316, 1972.
7. Grandhi RR, Brown RG. Thyroid metabolism in the recessive sex-linked dwarf female chicken. 3. The influence of exogenous thyroid hormones in glycogen metabolism. Poult Sci **54**:499–502, 1975.
8. Van Tienhoven A, Williamson JH, Tomlinson ME, MacInnes KL. Possible role of the thyroid and the pituitary glands in sex-linked dwarfism in the fowl. Endocrinology (Baltimore) **78**:950–957, 1966.
9. Grandhi RR, Brown RG, Reinhart BS, Sumners JD. Thyroid metabolism in the recessive sex-linked dwarf female chicken. 2. Binding of thyroid hormones by serum proteins. Poult Sci **54**:493–499, 1975.
10. Scanes CG, Marsh J, Decuypere E, Rudas P. Abnormalities in the plasma concentrations of thyroxine, triiodothyronine, and growth hormone in sex-linked dwarf and autosomal dwarf white leghorn domestic fowl (Gallus domesticus). J Endocrinol **97**:127–135, 1983.
11. Stewart PA, Washburn KW, Marks HL. Effect of the *dw* gene on growth, plasma hormone concentrations and hepatic enzyme activity in a randombred population of chickens. Growth **48**:59–73, 1984.
12. Hoshino S, Wakita M, Suzuki M, Yamamoto K. Changes in a somatomedin-like factor and immunoassayable growth hormone during growth of normal and dwarf pullets and cockerels. Poult Sci **61**:777–784, 1982.
13. Leung FC, Taylor JE, Steelman SL, Bennett CD, Rodkey JA, Long RA, Serio R, Weppleman RM, Olson G. Purification and properties of chicken growth hormone and the development of a homologous radioimmunoassay. Gen Comp Endocrinol **56**:389–400, 1984.
14. Barr AJ, Goodnight JH, Sall JD, Blair WH, Chiko DM. In: Helwig JT and Council KA, eds. SAS User's Guide, 1979 ed. Raleigh, N.C., SAS Institute.
15. Leung FC, Taylor JE, Van Iderstine A. Effects of dietary thyroid hormones on growth and serum T_3, T_4, and growth hormone in sex-linked dwarf chickens (41914). Proc Soc Exp Biol Med **177**:77–81, 1984.
16. Marsh JA, Gause WC, Sandhu S, Scanes CG. Enhanced growth and immune development in dwarf chickens treated with mammalian growth hormone and thyroxine (41806). Proc Soc Exp Biol Med **175**: 351–360, 1984.
17. Lilburn MS, Ngiam K, Smith JH, Leung FC. Body weight, carcass component characteristics and endocrine comparisons in normal, fast growing and sex-linked dwarf male and female chickens. Poult Sci **65**: 1458, 1983.
18. Stewart PA, Washburn KW. Hormone and lipogenic enzyme response of the heterozygous dw chick to dietary protein level. J Nutr **114**:132–143, 1984.
19. Reddy PRK, Siegel PB. Selection for body weight at eight weeks of age. 14. Effects of the sex-linked dwarf gene. Poult Sci **56**:1004–1013, 1077.
20. Leung FC, Gillett J, Lilburn MS, Kopchick J. Analysis of growth hormone receptors and genes in sex-linked dwarf chickens. J Steroid Biochem **20**(6B):1557, 1984.
21. Harvey S. Thyroid hormones inhibit growth hormone secretion in domestic fowl (Gallus domesticus). J Endocrinol **96**:329–334, 1983.
22. Harvey S, Sterling RJ, Klandorf H. Concentrations of triiodothyronine, growth hormone, and luteinizing hormone in the plasma of thyroidectomized fowl (Gallus domesticus). Gen Comp Endocrinol **50**:275–281, 1983.

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