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Plasma levels of growth hormone and insulin-like growth factor-I and -II from 2 to 6 weeks of age in meat-type chickens selected for 6-week body weight or for feed conversion and reared under high or normal environmental temperature conditions

E Decuypere [1], FR Leenstra [2], J Buyse [1], LM Huybrechts [1], FC Buonomo [3], LR Berghman [1]

[1] *Leuven Poultry Research Group, KU Leuven, Kardinaal Mercierlaan 92, 3001 Heverlee, Belgium;*
[2] *Spelderholt Centre for Poultry Research and Information Services (COVP-DLO), Beekbergen, The Netherlands;*
[3] *Monsanto Agricultural Company, 700 Chesterfield Village Parkway, Saint Louis, MI, USA*

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Summary — The aim of this study was to compare the effect of high (33°C) and normal (33–20°C) rearing temperature on growth and plasma levels of the somatotrophic hormones of 2 genetic lines of broiler chickens selected for 6-wk body weight (GL-line) or for feed conversion between 3 and 6 wk of age (FC-line) or for feed conversion between 3 and 6 wk of age (FC-line). Blood samples were collected weekly and analysed for growth hormone (GH) and insulin-like growth factors ((IGF)-I and -II levels by RIA.

The growth-depressing effect of the HT-treatment was more pronounced in the heavier GL-line and in males. A similar age-related pattern for all hormones studied was observed with the highest levels between 2 and 4 wk of age. FC-line chickens and males had consistently higher plasma GH levels than GL-line chickens and females respectively. No consistent effect of rearing temperature on plasma GH levels were observed. At 2 wk of age, HT-treatment resulted in higher plasma IGF-I levels while this was reversed from 3 wk of age onwards. GL-line chickens had significantly higher plasma IGF-I levels at 2, 3 and 4 wk of age. No consistent effect of sex on plasma IGF-I levels could be observed. For the whole period studied, GL-line chickens had significantly higher plasma IGF-II levels than FC-line chickens. No consistent effect of sex or temperature treatment on plasma IGF-II levels was observed.

ambient temperature / fat broiler / lean broiler / plasma levels / somatotrophic hormone

Résumé — Taux plasmatique des hormones de l'axe somatotrophe chez des poulets de chair sélectionnés pour leur croissance ou pour leur capacité de conversion alimentaire et élevés

à température forte ou modérée. *Le but de cette expérience consistait à comparer l'effet d'une température ambiante élevée (33°C) ou moyenne (33°C–20°C) sur le niveau des hormones de l'axe somatotrophe (GH, IGF-I et IGF-II) chez des poulets de chair sélectionnés soit sur leur vitesse de croissance (lignée GL) soit pour leur taux élevé de conversion alimentaire (lignée FC).*
L'effet dépressif des températures élevées sur la croissance est plus prononcé chez la lignée GL ainsi que chez les mâles des deux lignées. Un effet similaire est constaté pour les hormones en fonction de l'âge, atteignant un maximum entre 2 et 4 semaines. Les taux de GH dans le plasma sont plus élevés chez les poulets FC et chez les poulets mâles des deux lignées que chez les poulets de la lignée GL et chez les femelles. En ce qui concerne IGF-I et IGF-II, la lignée GL manifeste un niveau plasmatique plus élevé pour IGF-I à 2, 3 et 4 semaines ainsi que pour IGF-II mais alors pour l'ensemble de la période étudiée. Aucun effet du sexe sur les niveaux des IGF n'a été observé. La température ambiante n'a pas d'effet sur les niveaux de GH et IGF-II mais une température élevée induit un taux plasmatique de IGF-I croissant d'abord jusqu'à 3 semaines et puis décroissant.

température ambiante / poulets de chair, maigre ou gras / taux plasmatique / hormone somatotrophe

INTRODUCTION

Growth hormone (GH) plays an important role in the growth process of avian species (Scanes *et al,* 1984) and age-related changes in the circulating plasma concentrations of GH follow more or less the relative growth pattern (Burke and Marks, 1982; Stewart and Washburn, 1983). Between-sex comparisons of circulating GH levels generally demonstrate positive correlations with growth. Males exhibit both a faster growth rate and larger body size together with higher plasma GH concentrations compared to females (Johnson, 1988). However, when chicken lines are selected for different growth characteristics, the more rapidly growing lines generally demonstrate lower circulating GH levels (Scanes *et al,* 1980; Burke and Marks, 1982; Stewart and Washburn, 1983; Goddard *et al,* 1988; Leenstra *et al,* 1991). The higher GH levels in specific selected lines (Decuypere *et al,* 1991) as well as in males during the rapid growth phase (Johnson, 1988), are often characterized by a high amplitude of GH peaks.

Correlative studies often yield conflicting results as far as the relationship between plasma levels of insulin-like growth factor-I (IGF-I) and growth is concerned. Similar to GH, within-line temporal studies indicate a positive relation between IGF-I and growth rate (Huybrechts *et al,* 1985; Goddard *et al,* 1988). Scanes *et al* (1984) found higher plasma IGF-I levels in high weight selected lines of both dwarf and normal chickens compared to the low weight selected lines. However, Goddard *et al* (1988) did not find any differences in plasma IGF-I concentrations between growth-selected compared to selection-relaxed broilers while selection for body weight gain or for feed conversion did not reveal any differences in plasma IGF-I levels either (Leenstra *et al,* 1991). Contrary to the GH data, between-sex comparisons showed no effect of sex on IGF-I levels (Scanes *et al,* 1989; Leenstra *et al,* 1991).

Data on insulin-like growth factor-II (IGF-II) levels in growing chickens are rather scarce. Scanes *et al* (1989) reported markedly reduced plasma IGF-II levels in sex-linked dwarfs compared to normal chickens whereas plasma IGF-II levels in normal chickens selected for low body weight were slightly lower compared to chickens selected for high body weight. Faster-growing broiler chickens had higher

initial IGF-II levels but lower circulating IGF-II levels during the grow-out period compared to chickens of a laying strain while higher plasma IGF-II levels were found in females compared to males (Buonomo, 1989).

Although temperature, as an important environmental factor, profoundly affects growth rate of chickens, there is very little information on the effect of temperature on GH secretion in growing chickens and no information on the extent to which plasma IGF-I and IGF-II levels are affected by this environmental factor. Harvey *et al* (1977) observed lower circulating levels of GH after chickens had been exposed to cold for a short time while Scott and Washburn (1985a), using a turkey GH radioimmunoassay found slightly higher mean GH values after rearing random-bred chickens and growth-selected broiler strain crosses for 1 or 2 wk at 26.7°C compared to 32.2°C. One d-old commercial broiler chicks, however, showed depressed GH levels when brooded at 26.7°C compared to 32.2°C but this was reversed the second and third day under the same temperature conditions (Scott and Washburn, 1985b).

In view of the lack of information on IGF-II in growing chickens of different lines and on the effect of rearing temperature on somatotrophic hormones, the aim of this study was to compare plasma GH, IGF-I and IGF-II levels in 2 lines of broiler chickens selected for weight gain or for feed conversion and reared under 2 different temperature conditions during their rapid growth phase up to 6 wk of age.

MATERIALS AND METHODS

Chickens, housing and management

The chickens used in this experiment originated from the twelfth generation of 2 selection lines both originating from commercial broiler sire stocks. The GL-lines was selected for 6-wk body weight and the FC-line for food conversion between 3 and 6 wk of age. The history of these lines and information on production traits has been given elsewhere (Leenstra and Pit, 1987, 1988). The chicks were sexed and wing-banded at hatch and were housed by line and sex in litter pens (± 10 chicks per pen). The pens were arranged in 2 environmentally controlled rooms. In one room, the temperature was 33°C up to 2 wk of age and 32°C thereafter (high temperature treatment, HT). The temperature in the other room was gradually reduced from 33°C at hatch to 29°C at 2 wk of age, 23°C at 4 wk of age and 20°C from 5 wk onwards (normal temperature treatment, LT). To prevent leg disorders, 1 h light was alternated with 3 h darkness (6 x (1L:3D)) until 3 wk of age; thereafter continuous lighting was provided. A pelleted broiler diet containing 13.1 ME MJ and 220 g crude protein/kg and water were provided *ad libitum*.

Experimental design

Per line by sex by temperature combination, 18 chickens were available except for GL males where 11 (LT treatment) or 10 (HT treatment) chickens were used. Body weight was recorded weekly per pen. At 2, 3, 4, 5 and 6 wk of age, a blood-sample of ≈ 1 ml was taken from the wing vein of each chicken using EDTA as anticoagulant. When chickens were under 1L:3D, blood-samples were taken during the light period. The blood-samples were kept on ice and centrifuged within 30 min. The plasma was removed and immediately stored at –20°C until analysis.

Hormone assays

Chicken growth hormone was measured by a homologous radioimmunoassay as described earlier (Decuypere *et al*, 1991). The characterization of the chicken GH and the specificity of the monoclonal antibodies used to develop the assay have been discussed by Berghman *et al* (1988). The detection limit of the assay was 2 ng/ml and the intra- and interassay variation coefficients were 4.0 and 15.5% respectively. The plasma concentration of IGF-I was measured

with a heterologous radioimmunoassay (Huybrechts *et al*, 1985). The intra- and interassay coefficients of variation were 6.9% and 20.2% respectively. Plasma IGF-II concentrations were determined by the heterologous radioimmunoassay of Buonomo *et al* (1988) with intra- and inter-assay coefficients of variation of 4.9% and 7.6% respectively.

Statistical analysis

The hormone concentrations in plasma were subjected to analysis of variance with temperature, line and sex as fixed effects (Genstat, 1987). To examine the effect of age and interactions of line, sex and temperature with age, the data were initially analysed according to a model with age as a polynomial crossed with line, sex and temperature. Age significantly interacted with the other main factors and consequently only the results of ANOVA within age are presented. The data of the individual chickens were considered independent. The number of observations per line by sex by temperature combination varied, but in all cases exceeded 9, while for most groups at least 16 observations were available. The data for GH at 4 wk of age was the only data set that was not normally distributed. As level of significance for the experimental factors was not affected by transforming these data to their log-values (that had a normal distribution), all analyses were carried out on the untransformed data. Body weight and body weight gain were not analysed statistically.

RESULTS

Body weight and weekly body weight gains from 0 to 6 wk of age are given by line and temperature, both for males and females in figure 1. Line, sex and temperature effects on body weight and body weight gain were as expected from other experiments with

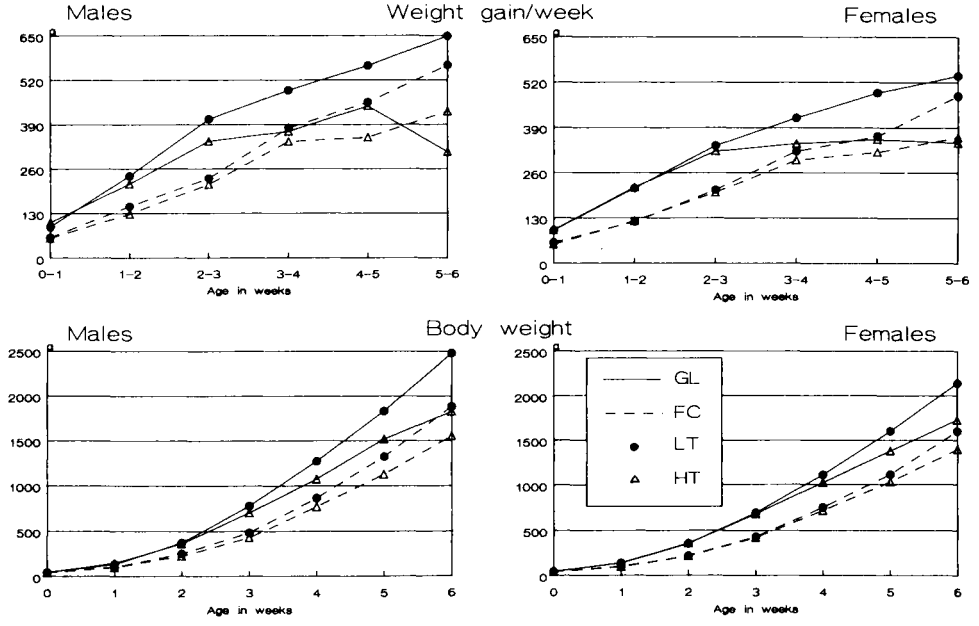

Fig 1. Body weight and weekly body weight gains of male and female chickens from broiler lines selected for 6-wk body weight (GL) or for feed conversion between 3 and 6 wk of age and reared under high (HT, 33°C) or normal (LT, 33–20°C) temperature conditions.

these lines (Cahaner and Leenstra, 1992). Temperature effects were more pronounced on both parameters in the GL-line compared to the FC-line and in males compared to females.

Results of the analysis of variance and mean plasma concentrations of GH are presented in table I. Although in several cases interactions were significant, means for main effects are also given for a general and uniform overview. Table II shows significance and direction of differences between means by line, sex and temperature. In general, interactions did not change the rank order of the treatments, but affected the magnitude of differences. In almost all comparisons of the lines within age, sex and temperature, significantly higher GH levels were found in the FC-line compared to the GL-line, while males exhibited higher GH levels than females. An age-related plasma GH pattern was evident in both lines and sexes. A temperature effect on GH was not observed until 6 wk of age where significantly higher GH values were found at the lower rearing temperature (table I). No consistent interactions of lines and sexes with temperature were found. The high levels of GH at 2, 3 and 4 wk of age coincided with high coefficients of variation of these values (table III). For males, no consisted differenc-

Table I. Results of the analysis of variance (*P* levels) and mean concentrations of growth hormone (ng/ml) in blood-plasma of male and female chickens of 2 genetic lines.

	Parameter: Age (wk)				
Variables	*2*	*3*	*4*	*5*	*6*
Temperature (T)	NS[a]	NS	NS	0.064	0.005
Line (L)	< 001	< 001	< 001	< 001	< 001
Sex (S)	< 001	< 001	< 0.011	< 001	< 001
T x L	NS	NS	NS	NS	NS
T x S	NS	0.042	0.081	0.053	NS
L x S	NS	NS	0.002	0.068	NS
T x L x S	0.004	NS	NS	0.013	NS
Low T	32.8	33.1	36.8	28.6	20.6
High T	35.6	31.1	36.5	25.6	18.2
GL line	27.5	21.4	27.4	21.7	17.8
FC line	40.9	42.8	45.9	32.5	21.0
Males	40.0	36.2	40.2	33.6	22.5
Females	28.3	28.1	33.1	20.6	16.3
GL males LT	27.0	24.3	35.0	28.9	20.8
GL males HT	41.8	25.2	35.7	24.6	20.3
GL females LT	22.8	20.4	20.3	17.9	16.4
GL females HT	18.3	15.8	18.6	15.4	13.8
FC males LT	48.3	46.3	40.9	38.2	25.4
FC males HT	43.0	48.9	49.2	42.8	23.6
FC females LT	33.1	41.6	51.2	29.4	19.7
FC females HT	39.1	34.4	42.4	19.6	15.2
SED	5.15	3.73	5.50	3.18	1.66

GL: selected for body weight at 6 wk and FC: selected for feed conversion from 3 to 6 wk of age kept at high and low temperature (SED: standard error of difference for the 3-way interaction; $n \geq 9$). [a] $P > 0.10$.

Table II. Significant differences between combinations of line (GL selected for body weight at 6 wk, FC selected for feed conversion from 3 to 6 wk of age), sex (M: male, F: female) and temperature (LT: 33–20°C, HT: 33°C) for plasma concentrations of GH, IGF-I and IGF-II at different ages *.

Parameters:	*GH*					*IGF-I*					*IGF-II*				
	Age (wk)					*Age (wk)*					*Age (wk)*				
Variables	*2*	*3*	*4*	*5*	*6*	*2*	*3*	*4*	*5*	*6*	*2*	*3*	*4*	*5*	*6*
Temperature (LT: LT ≥ HT; HT: LT < HT)															
GL M	HT	NS	NS	NS	NS	HT	LT	LT	LT	LT	NS	NS	NS	LT	HT
GL F	NS	NS	NS	NS	NS	HT	LT	LT	LT	NS	NS	NS	NS	NS	NS
FC M	NS	NS	NS	NS	NS	HT	NS	LT	LT	NS	NS	NS	NS	NS	NS
FC F	NS	NS	NS	LT	NS	HT	NS	LT	LT	NS	HT	LT	LT	LT	NS
Line (GL: GL > FC; FC: GL < FC)															
LT M	FC	FC	NS	FC	NS	GL	GL	NS	NS	GL	GL	GL	GL	GL	NS
LT F	FC	FC	FC	FC	NS	NS	GL	GL	NS	NS	GL	GL	GL	GL	NS
HT M	NS	FC	FC	FC	NS	GL	GL	NS	NS	FC	NS	GL	GL	NS	GL
HT F	FC	FC	FC	NS	NS	GL	GL	GL	NS	NS	NS	GL	GL	GL	GL
Sex (M: M > F; F: M < F)															
LT GL	NS	NS	M	M	M	NS	NS	NS	NS	NS	F	NS	NS	NS	NS
LT FC	M	NS	NS	M	M	F	NS	M	NS	NS	NS	F	F	NS	F
HT GL	M	M	NS	M	M	F	NS	NS	NS	F	NS	NS	NS	F	M
HT FC	NS	M	NS	M	M	NS	NS	NS	NS	F	F	NS	NS	NS	NS

* If a difference is significant ($P \leq 0.05$) the larger of the 2 treatments is given.

Table III. Coefficients of variation (%) for plasma growth hormone concentrations of male and female chickens of 2 genetic lines (GL selected for 6-wk body weight and FC selected for food conversion between 3 and 6 wk of age) kept at high (33°C) or low (33–20°C) temperature.

	Parameter: Age (wk)				
Chickens	*2*	*3*	*4*	*5*	*6*
GL male LT	44.0	31.3	34.6	37.0	28.8
GL male HT	55.0	31.0	22.1	39.0	27.1
GL female LT	43.0	34.3	32.5	18.4	25.6
GL female HT	28.4	13.3	15.1	14.3	16.7
FC male LT	38.1	27.0	40.3	25.9	21.7
FC male HT	41.4	23.3	33.1	31.3	32.6
FC female LT	56.8	45.0	54.3	46.9	22.8
FC female HT	39.9	34.0	49.5	37.8	19.5

es in coefficients of variation between the lines could be observed while for females, the coefficients of variation averaged higher for FC chickens compared to GL chickens. For GL chickens, the coefficients of variation for females were reduced compared to males but only when reared at high temperature. In contrast, for FC chickens coefficients of variation of females averaged higher compared to those of their male counterparts at both rearing temperatures. A decrease in coefficients of variation due to the high rearing temperature was only observed for female chickens of both lines.

An effect of rearing temperature on circulating levels of IGF-I could be demonstrated (tables II, IV). At 2 wk of age, HT-treatment resulted in higher IGF-I values in both lines and sexes, the effect being more pronounced in the GL-line resulting in a significant T x L interaction. Between 2 and 3 wk of age, the temperature effect was reversed and higher levels were then found in the LT-treatment. This reversal was more pronounced in the GL-line, resulting again in a T x L interaction at 3 wk of age. The higher IGF-I values at the lower rearing temperatures from 3 weeks of age on-

Table IV. Results of the analysis of variance (*P* levels) and mean concentrations of insulin-like growth factor-I (IGF-I, ng/ml) in blood-plasma of male and female chickens of 2 genetic lines (GL: selected for body weight at 6 wk and FC: selected for feed conversion from 3 to 6 wk of age) kept at high and low temperature.

	Parameter: Age (wk)				
Variables	*2*	*3*	*4*	*5*	*6*
Temperature (T)	< 001	< 001	< 001	< 001	0.002
Line (L)	< 001	< 001	0.009	NS [a]	NS
Sex (S)	< 001	NS	NS	NS	NS
T x L	< 001	0.001	NS	NS	< 001
T x S	NS	NS	0.052	NS	< 001
L x S	NS	NS	0.047	NS	0.079
T x L x S	0.004	NS	NS	NS	0.016
Low T	6.60	20.52	19.26	16.66	14.36
High T	15.74	17.30	15.88	13.68	12.82
GL line	12.32	21.86	18.26	15.40	13.40
FC line	9.74	15.98	16.88	14.94	13.76
Male	10.30	15.56	17.46	14.98	13.20
Female	12.06	19.28	17.68	15.36	13.98
GL males LT	7.02	24.36	19.66	17.46	16.52
GL males HT	17.06	18.18	15.60	13.44	10.36
GL females LT	6.64	24.94	20.14	16.98	13.46
GL females HT	19.78	19.94	17.64	13.74	13.26
FC males LT	4.50	16.68	19.68	15.70	13.20
FC males HT	12.60	15.00	14.90	13.36	12.68
FC females LT	8.30	16.14	17.60	16.48	14.22
FC females HT	13.58	16.08	15.34	14.20	14.94
SED	0.99	1.40	1.03	0.90	0.97

SED: standard error of difference for the 3-way interaction; $n \geq 9$. [a] $P > 0.10$.

wards were very consistent in both lines and sexes. At 6 wk of age, the LT-treatment still showed higher IGF-I values in males chickens of the GL-line and no longer in females and in FC chickens, resulting in a significant T x L and T x S interaction.

A consistent and significantly higher plasma IGF-II level was found in the GL-line over the period studied (tables II, V). Both lines exhibited similar age-related changes with a maximum at the age of 3 wk. As regards IGF-I, no effect of sex on IGF-II levels was observed, except for wk 2 where slightly higher values were observed in females. In contrast with IGF-I, no consistent effect of rearing temperature could be found. Only at the age of 5 wk did the LT-treatment result in overall higher IGF-II values compared to the HT-treatment, while this was reversed at 6 wk of age.

Table V. Results of the analysis of variance (*P* levels) and mean concentrations of insulin-like growth factor-II (IGF-II, mg/ml) in blood plasma of male and female chickens of 2 genetic lines (GL: selected for body weight at 6 wk and FC: selected for feed conversion from 3 to 6 wk of age) kept at high and low temperature.

	Parameter: Age (wk)				
Variables	*2*	*3*	*4*	*5*	*6*
Temperature (T)	NS[a]	NS	NS	< 001	0.002
Line (L)	0.002	< 001	< 001	0.004	< 001
Sex (S)	0.002	0.082	NS	0.075	NS
T x L	< 001	NS	NS	NS	NS
T x S	NS	0.024	NS	NS	0.001
L x S	NS	NS	< 001	NS	< 001
T x L x S	0.028	NS	0.057	0.067	NS
Low T	14.5	16.9	14.5	15.2	12.8
High T	15.6	16.3	14.2	13.5	14.4
GL line	16.1	18.5	16.0	15.1	14.6
FC line	14.0	14.7	12.7	13.6	12.5
Male	14.0	16.1	14.1	13.9	13.9
Female	16.1	17.1	14.6	14.8	13.3
GL male LT	15.4	18.3	16.8	16.0	13.2
GL male HT	14.2	18.4	16.9	13.1	18.5
GL female LT	18.6	19.3	15.0	16.0	12.7
GL female HT	16.4	17.9	15.4	15.3	14.1
FC male LT	12.6	13.2	10.8	13.8	11.4
FC male HT	13.8	14.4	12.1	12.8	12.4
FC female LT	11.5	16.8	15.4	15.1	14.0
FC female HT	17.9	14.3	12.5	12.8	12.4
SED	1.35	1.15	1.17	0.97	0.99

SED: standard error of difference for the 3-way interaction; $n \geq 9$. [a] $P > 0.10$.

DISCUSSION

The higher body weight of the GL-line compared to that of the FC-line confirms earlier data (Leenstra and Pit, 1987, 1988 ; Leenstra *et al,* 1991). The depressive effect of high environmental temperatures on body weight and growth rate has been well documented (Howlider and Rose, 1987). The more pronounced effect of rearing temperature on growth parameters in the heavier GL-line and in male broilers is also consistent with the earlier findings of Cahaner and Leenstra (1992).

The age-related changes in plasma GH concentrations as well as the higher GH levels found in male broilers compared with females during the ascendent growth phase confirm earlier data (Johnson, 1988; Buyse *et al,* 1991; Leenstra *et al,* 1991). Differences in mean GH concentrations between GL and FC chickens are in agreement with earlier findings (Decuypere *et al,* 1991; Leenstra *et al,* 1991). Moreover, Decuypere *et al* (1991) observed higher GH peak amplitudes (pulse height above baseline) for cannulated FC chickens compared to GL chickens. As no difference in baseline levels were observed, the higher coefficients of variation of FC chickens resulted from their significantly higher peak amplitudes compared to GL chickens. This was also observed in another study in which cannulated chickens of both lines were reared under the same environmental temperatures as used here (Buyse *et al,* submitted). In the present study, a line difference in coefficients of variation – indicative for GL pulse height *ceteris paribus* – was only apparent for female chickens (table III). For male chickens, the SDs around the means differed clearly between the lines but due to differences in means, the coefficient of variation did not. Also, the sexual dimorphism in GH secretory profiles as observed by Johnson (1988) was less clear in our study as could be inferred from examining the coefficients of variation. In accordance with the conclusions of Vasilatos-Younken and Scanes (1991) in a review on growth hormone in chickens, our data support the idea that within lines, GH is most often positively correlated with growth rate as it is in between-sex comparisons. Between lines however, correlations are often negative, indicating that plasma GH levels *per se* are not indicative for growth potential of genetic lines.

The absence of any temperature effect on mean GH levels at a young age in our study have been confirmed in another experiment (Buyse *et al,* submitted) and are not necessarily contradictory with the observed effects (increase or decrease) of acute temperature decrease on GH in very young chicks (Harvey *et al,* 1977; Scott and Washburn, 1985a, 1985b) or with the observation of an increased plasma GH level when broilers were exposed to high ambient temperature (35°C) for 5 h a day and otherwise maintained at 21°C (Sinurat *et al,* 1987). Our temperature changes were gradual and applied over a longer period of time, as well as at an older age. Although the high rearing temperature had a pronounced and expected effect on growth rate, this was not paralleled by changes in GH level, indicating that not only are GH levels as such not indicative of genetic growth potential, but not even necessarily for realized growth as it may be influenced by exogenous factors. As already stated by Vasilatos-Younken and Scanes (1991), the multitude of factors that contribute to effective GH action, such as synthesis, secretion, clearance, GH receptor capacity and affinity and interactions with other hormones explain why a simple measure of GH such as its plasma concentration is not always consistent or highly correlated with growth. However, the high rearing temperature abolished the episodic release of GH, as observed from the reduced coeffi-

cients of variation – indicative of a reduced or disappearance of GH pulses – at least in females and as explicitly observed for male chickens of both lines (Buyse *et al,* submitted). Moreover, line differences as well as a changed GH response upon a thryotropin release hormone (TRH) challenge and an altered GH elimination rate from the plasma due to a higher ambient temperature have been observed previously (Herremans *et al,* 1991). Plausible causal mechanisms relating TRH-induced GH release and GH elimination rate and the presence or absence of GH secretory spikes in the plasma have been discussed elsewhere (Herremans *et al,* 1991 ; Buyse *et al,* submitted).

An age-related decrease in plasma IGF-I as well as in IGF-II from 3 wk of age onwards was observed and this was particularly clear in the GL-line. Similar age-related changes in plasma IGF-I (Huybrechts *et al,* 1985; Goddard *et al,* 1988) and IGF-II levels (Buonomo, 1989) have already been described. A clear line effect was present at all ages, the heavier GL line having higher plasma IGF-II levels. Scanes *et al* (1989) could not observe any differences in plasma IGF-II concentrations between high and low weight selected normal chicken lines, but for dwarfs, plasma concentrations of IGF-II were greater in the high weight line. Buonomo (1989) reported that faster-growing broiler chickens had higher initial IGF-II levels but lower circulating IGF-II levels during the grow-out period compared to chickens of a laying strain. The absence of sexual dimorphism with respect to plasma IGF-II levels is in agreement with the findings of Scanes *et al* (1989), but not with those of Buonomo (1989) who observed higher plasma IGF-II levels in females compared to males. Although the absence of a specific IGF-II receptor in the chicken and a similar affinity of both IGF-I and IGF-II for the IGF-I receptor may indicate a similar biological activity of both peptides in the chicken (Duclos and Goddard, 1990), the physiological significance of differences in plasma IGF-II levels remains to be elucidated since, as for GH, a momentaneous measure may not always be correlated with effective action.

At least until 4 wk of age, plasma IGF-I levels of GL chickens averaged significantly higher compared to those of the slower growing FC chickens. However, Leenstra *et al* (1991) did not observe any differences in circulating plasma IGF-I levels between these genotypes. Differences in lighting program (continuous light from hatch onwards in the experiment of Leenstra *et al* (1991) and intermittent lighting until 3 wk of age in our study) or an extra 2 generations of selection may account for this discrepancy between both experiments. Temperature basically did not affect plasma IGF-II levels, while a consistent lower IGF-I level in both lines and sexes at the higher temperature was found. This is consistent with the lower body weight gain of both lines and sexes while a significant line and temperature interaction as well as a sex and temperature interaction for both IGF-I and body weight gain further support the linkage between IGF-I and growth. Indeed, the HT-treatment had a greater depressive effect on the heavier males of the GL-line for both growth and IGF-I. Studies in which dietary manipulations (Harvey *et al,* 1984; Lauterio and Scanes, 1987; Vasilatos-Younken and Scanes, 1991) have altered growth rate as well as IGF-I levels, further strengthen this positive relationship between IGF-I and growth. The complete reversal of the HT-treatment on IGF-I levels in both lines and sexes, without exception, between wk 2 and wk 3 points to a more complex effect of temperature on IGF-I levels.

It may be relevant to mention that changes in plasma concentrations of T_3

and to some extent of T_4 in young growing chicks of a laying strain in response to cold exposure were opposite depending on the length of exposure (Decuypere and Kuhn, 1988). The importance of the time factor in the interpretation of changes in thyroid hormone concentrations in response to a temperature stressor has already been mentioned by Bobek *et al* (1980). Plasma hormone levels are indeed the integrated result of production and release (input) and elimination and tissue utilization (output). Whatever regulates these input–output factors probably does not change simultaneously upon changes in ambient temperature. Interpretation of changes in plasma GH, IGF-I and IGF-II levels upon changing environmental factors such as temperature, therefore, will need quantification of a qualitative model of input–output factors regulating plasma hormone concentrations.

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