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Analysis of growth characteristics in short-term divergently selected Japanese quail

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Abstract

This study was carried out to examine the effect of short-term selection for 5-weeks of age body weight in divergent lines of Japanese quail. Growth curves for both sexes within each selection group resembled the general sigmoid shape of a typical growth curve. Gompertz model curves and the observed growth curves were very similar. In both males and females the parameter estimates of the Gompertz growth curve were obtained with a high determination coefficient ($0.9898 \geq R^2 \geq 0.9840$). Sex differences in asymptotic weight were found to be significant across lines. Similarly, in both sexes a significant divergent selection effect was determined for parameter A. The growth rate in all the Japanese quail lines was significantly higher in males than in females. There was also a significant increase in growth rate of the females selected for increased 5-week body weight over the control females, as well as a significant decline in growth rate of males selected for decreased 5-week body weight compared to the unselected control group.

Keywords: Gompertz model, growth curve, asymmetric response, growth rate
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Introduction

Growth is a priority trait in the poultry industry. The Japanese quails (*Coturnix coturnix japonica*) have been used widely as a model species in research on poultry breeding and the genetics of growth traits, because they are small, less expensive than chickens and turkeys, have a short generation interval and show genetic variation for growth traits in most populations (Wilson *et al.*, 1961; Marks, 1990). The growth pattern or growth curve of animals for body weight or body parts is described by growth functions. The general shape of the growth curve is a sigmoid form and is generally modelled by Logistic, Gompertz or Bertalanffy growth functions, which summarize the information into a few biologically interpretable parameters (Tzeng & Becker, 1981; Goliomytis *et al.*, 2003).

There are a number of reported studies on the effect of selection on growth in Japanese quails: Marks (1978) reported that growth curve parameters were changed by selection for body weight in Japanese quail. The use of Logistic, Gompertz and Bertalanffy models was compared using the growth patterns from a study on divergent selection on 4-week body weight (Anthony *et al.*, 1986). Hyankova *et al.* (2001) also found that the shape of the growth curve was affected by short-term selection. However, Anthony *et al.* (1996) reported that the shape of the growth curve was not affected by short-term selection in the Japanese quail. Akbaş & Oğuz (1998) used three nonlinear growth models in selected and non-selected quail lines. The heritability estimates of growth curve parameters were studied in unselected quails, using the Gompertz model (Akbaş & Yaylak, 2000). In unselected chicken populations, Aggrey (2002) compared three non-linear models (Richards, Gompertz and Logistic) and the spline regression model.

Most poultry growth data have been fitted with the Gompertz model (Anthony *et al.*, 1986; 1991; Hurvitz *et al.*, 1991; Akbaş & Oğuz, 1998). Therefore, the aim of the present study was to determine the effect of divergent selection for 5-week body weight on growth curve parameters of Japanese quail, using the Gompertz model.

Materials and Methods

Two divergently selected lines and a control (CL line) were used in this study. Over five generations a high (HL line) and a low (LL line) line were established by selecting Japanese quail chicks for high and low

5-week body weights. Quail chicks were hatched and wing-banded on day of hatch. Their pedigree records were taken on the same day. The quail lines were raised in separate brooder batteries. At five weeks of age sex identification was carried out according to plumage and colour pattern. Their diet contained 240 g crude protein/kg and 10.8 MJ ME/kg. All birds had *ad libitum* access to the diet and water during the experimental period.

Until eight weeks of age body weights were recorded on all birds, as well as weekly body weights. Individual selection for body weight at five weeks of age was applied, with selection intensities of 10% and 40% for males and females, respectively. Mating was random, to minimize inbreeding. Growth records (352, 272, and 619) from HL, LL and CL lines, respectively, were used in the analysis. Data of individual body weights of quails were analyzed using the Gompertz model described by Ricklefs (1967) as:

$$\mathbf{Y_t = A\ exp(-Bexp(-Kt))}$$

where, Y_t is the body weight (g) of birds at t weeks of age ($t = 0, 1,\ldots, 8$); A, B and K are model parameters: A is asymptotic weight when time goes to infinity; B is a scaling parameter (constant of integration), which is related with initial values of Y, and K is relative growth rate.

Weight and age at the inflection point (POI) were calculated as $\mathbf{Y_I = A/e}$ and $\mathbf{t_I = ln(B)/K}$, respectively. The growth curve functions were fitted individually to the observed data by using a non-linear regression procedure with Marquardt algorithm (SAS, 1999). During the iteration procedure, when any parameter values at a current iteration did not change in the successive iteration, the procedure stopped and it was assumed that the convergence criteria of 1.0E-05 was attained. However, when the iteration for some birds did not converge, they were excluded from the analysis. The differences between lines and sex within lines for the Gompertz model parameters were tested using PROC GLM (SAS, 1999).

Results and Discussion

Means of body weights and the standard errors at various ages for both sexes within the HL, CL and LL lines are presented in Table 1. Within the HL and LL lines body weight means of females and males were found to be similar from hatch to four weeks of age, and within the CL line from hatch to three weeks of age. After these ages the body weight of the females was found to be higher ($P < 0.05$) than that of the males. Similar results were reported by Anthony *et al.* (1986), Du Preez & Sales (1997), Hyankova *et al.* (2001) and Aggrey *et al.* (2003). Japanese quails exhibit sexual dimorphism in body weight. According to Oğuz *et al.* (1996) females are heavier than males, and this difference becomes apparent at about the third or fourth week of age. The effects of short-term divergent selection for 5-week body weight were found to be important when comparing the HL and LL lines to the CL line for hatching weight (Table 1). The significant effect ($P < 0.05$) of selection also continued throughout the growing period. These results agree with those of Anthony *et al.* (1986) and Aggrey *et al.* (2003), but not with the results of Hyankova *et al.* (2001). Although these effects were attributed to the relationship between egg size and body weight of the female (Sefton & Siegel, 1974; Marks, 1975), it was reported that maternal effects would be expected to be overcome by genetic abilities of the individual bird (Anthony *et al.*, 1986).

For observed body weights, the percentage deviation of the HL and the LL lines from the CL line is presented in Figure 1. Selection responses for body weight in the HL and LL lines were asymmetrical throughout the growth period. Differences between the HL and the LL lines occurred during the first three weeks of age. After this growth rates declined in both these lines and ran parallel with the CL line. These results agree with those from Anthony *et al.* (1986), Darden & Marks (1988), Hyankova *et al.* (2001) and Aggrey *et al.* (2003).

The growth patterns of the sexes were different. Therefore, data sets were analysed separately for each sex within line. The observed growth curve and the estimated Gompertz curve of each selection line are presented in Figure 2 for males and in Figure 3 for females. Growth curves for both sexes within each selection group resembled the general sigmoid shape. Gompertz model curves and the observed growth curves were very similar. From growth curve analyses, the estimates of Gompertz function parameters (A, B, and K), weight and age at the (POI), coefficient of determination and residual variance are given in Table 2. The estimates of the Gompertz growth curve were obtained with high determination coefficients ($0.9898 \geq R^2 \geq 0.9840$) in both males and females. This implies that the growth curves of the observed data were adequately described by the Gompertz function, in agreement with Ricklefs (1973), Tzeng & Becker (1981), Anthony *et al*. (1986) and Akbaş & Oğuz (1998).

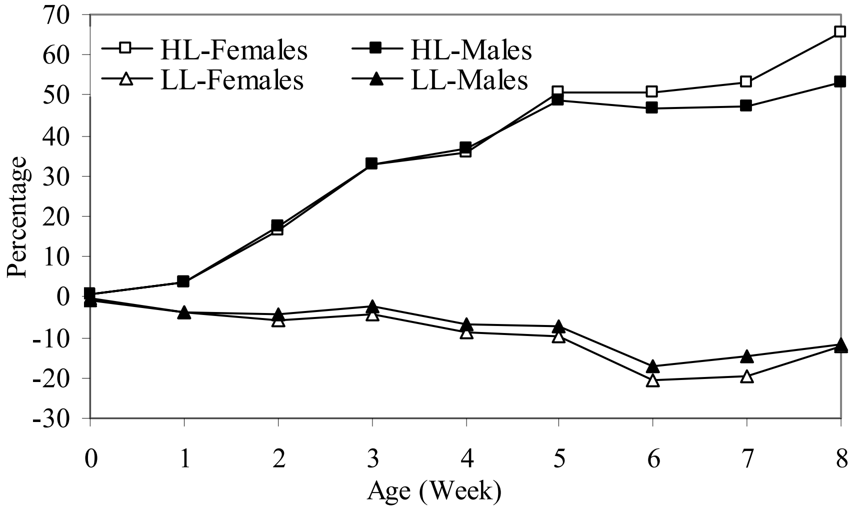

Figure 1 Deviations (%) from the control (0%) in body weights of lines selected for high (HL) or low (LL) body weights at five weeks of age

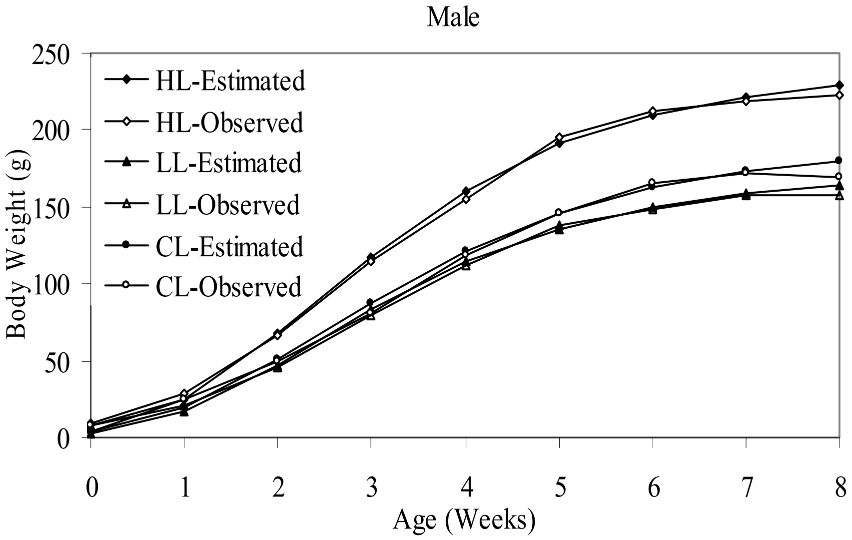

Figure 2 Observed and predicted growth curves for males selected for high (HL) or low (LL) body weights at five weeks of age, compared to the control (CL)

Table 1 Means and standard errors for body weight at different ages in three experimental Japanese quail lines

	High line		Low line		Control line	
Age (week)	Female (n = 172)	Male (n = 180)	Female (n = 134)	Male (n = 138)	Female (n = 296)	Male (n = 323)
0	8.8 ± 0.07^{aA}	8.7 ± 0.07^{aA}	7.6 ± 0.05^{aA}	7.5 ± 0.05^{aA}	8.1 ± 0.04^{aB}	8.1 ± 0.04^{aB}
1	28.3 ± 0.39^{aA}	28.5 ± 0.38^{aA}	21.0 ± 0.33^{aA}	21.4 ± 0.32^{aA}	24.8 ± 0.23^{aB}	25.0 ± 0.22^{aB}
2	65.7 ± 1.04^{aA}	66.9 ± 0.91^{aA}	43.4 ± 0.83^{aA}	45.1 ± 0.75^{aA}	49.2 ± 0.57^{aB}	49.2 ± 0.45^{aB}
3	115.6 ± 1.63^{aA}	114.4 ± 1.37^{aA}	78.6 ± 1.20^{aA}	79.2 ± 1.16^{aB}	82.8 ± 0.82^{aB}	81.3 ± 0.65^{aB}
4	157.6 ± 1.95^{aA}	155.2 ± 1.56^{aA}	113.2 ± 1.23^{aA}	111.3 ± 1.24^{aA}	121.8 ± 0.98^{aB}	118.3 ± 0.83^{bB}
5	203.9 ± 1.88^{aA}	194.7 ± 1.31^{bB}	143.7 ± 1.16^{aA}	138.6 ± 1.05^{bA}	153.3 ± 1.00^{aB}	146.0 ± 0.82^{bB}
6	238.3 ± 2.15^{aA}	212.1 ± 1.32^{bB}	167.1 ± 1.22^{aA}	148.1 ± 1.10^{bA}	187.9 ± 1.29^{aB}	165.4 ± 0.83^{bB}
7	257.8 ± 2.09^{aA}	218.6 ± 1.41^{bB}	185.0 ± 1.43^{aA}	157.2 ± 1.07^{bA}	204.4 ± 1.30^{aB}	171.6 ± 0.98^{bB}
8	265.2 ± 1.92^{aA}	222.5 ± 1.52^{bB}	187.5 ± 1.62^{aA}	157.5 ± 0.95^{bA}	199.6 ± 1.35^{aB}	169.1 ± 0.91^{bB}

^{a,b}Means with different superscripts are significantly different ($P < 0.05$) between the sexes (female and male) within line
^{A,B}Means with different superscripts are significant different ($P < 0.05$) between lines and control within the sexes (female and male)

Table 2 Estimates of growth curve parameters in three experimental Japanese quail lines

	High line		Low line		Control line	
Parameters	Female	Male	Female	Male	Female	Male
Gompertz Model parameters						
A (g)	304 ± 2.9^{aA}	237 ± 2.8^{bA}	213 ± 1.7^{aA}	70 ± 1.7^{bA}	239 ± 1.7^{aB}	189 ± 1.7^{bB}
B	3.93 ± 0.044^{a}	4.06 ± 0.043^{bA}	3.96 ± 0.047^{a}	4.10 ± 0.046^{bA}	4.00 ± 0.039^{a}	3.90 ± 0.037^{bB}
K (g/week)	0.47 ± 0.006^{a}	0.58 ± 0.006^{bA}	0.47 ± 0.007^{a}	0.58 ± 0.007^{bA}	0.46 ± 0.006^{a}	0.54 ± 0.005^{bB}
Y_i (g)	112.1 ± 1.08^{aA}	87.3 ± 1.05^{bA}	78.3 ± 0.65^{aA}	62.6 ± 0.64^{bA}	87.9 ± 0.65^{aB}	9.6 ± 0.62^{Bb}
T_i (week)	2.99 ± 0.044^{a}	2.41 ± 0.043^{bA}	2.96 ± 0.041^{a}	2.47 ± 0.040^{bA}	3.07 ± 0.023^{a}	2.55 ± 0.029^{bB}
R^2	0.985	0.989	0.989	0.989	0.984	0.987
Residual Variance (g^2)	463.7	271.9	155.9	127.5	298.0	180.3

^{a,b}Values with different superscripts are significantly different ($P < 0.05$) between the sexes (female and male) within line
^{A,B}Values with different superscripts are significantly different ($P < 0.05$) between lines and control within the sexes (female and male)

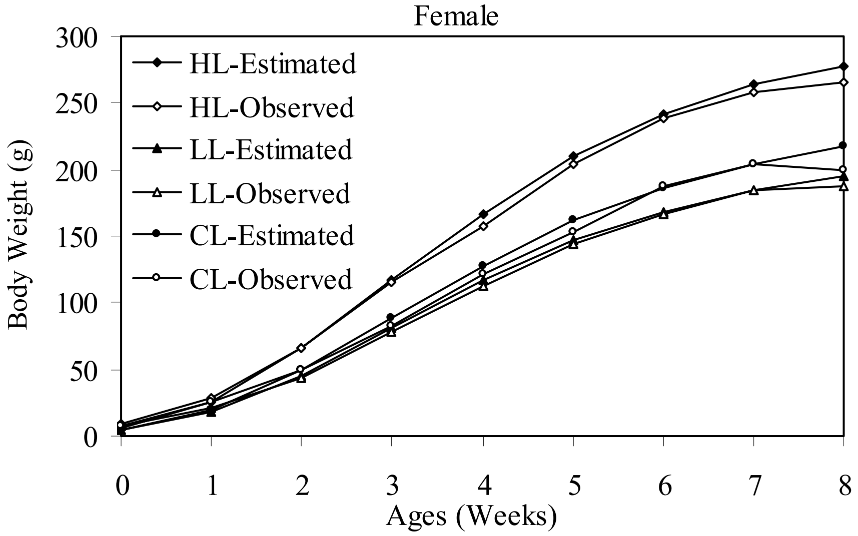

Figure 3 Observed and predicted growth curves for females selected for high (HL) or low (LL) body weights at five weeks of age, compared to the control (CL)

The parameters of the Gompertz equation were generally affected by divergent selection and sex. Asymptotic weights (estimates of parameter A) were higher in females ($P < 0.05$) than in males for all lines. Sex differences in parameter A were also reported in European quail (Du Preez & Sales, 1997) and Japanese quail (Akbaş & Oğuz, 1998; Akbaş & Yaylak, 2000; Aggrey *et al.*, 2003). There were significant ($P < 0.05$) asymptotic weight differences between the HL line and the CL line and between the LL line and the CL line for males and females ($P < 0.05$). These results revealed the effect of divergent selection for 5-week body weight on the asymptotic weights of quails. Asymptotic weights for females and males in HL were about 27.5% and 25.4% heavier than the CL females and males, respectively. However, the LL females and males were about 0.89% and 10.05% lower than the CL females and males, respectively. These results indicated that the HL line and the LL line responded differently to selection.

Parameter B (scale parameter) is related to initial weight (hatching weight) of the quails. The differences between the estimates of parameter B for females and males were found to be significant ($P < 0.05$). Although the B parameter estimate of females was higher than that of males in the CL line, they were higher in males than in females for the divergent selection lines. Kızılkaya *et al.* (2004) also found that the B estimate of females was higher than that of males for the Gompertz model in non-selected quails. However, Akbaş & Oğuz (1998) reported a larger estimate of the B parameter for males than for females in the Gompertz model. Akbaş & Yaylak (2000) determined non-significant differences between females and males for the B parameter in the Gompertz equation for non-selected quails. Although the effect of divergent selection on the B parameter estimate was significant in males, non-significant results were found in females.

Parameter K describes the rate or earliness of maturity. The smaller value estimate indicates longer periods of growth and higher mature weights. Akbaş & Yaylak (2000) and Kızılkaya *et al.* (2004) reported a negative correlation between parameters A and K for Japanese quails. As evident from Table 2, a significant effect of sex was determined on the estimates of K within selected and control lines. The K parameter estimates were larger in males than in females. Du Preez & Sales (1997), Akbaş & Oğuz (1998), Akbaş & Yaylak (2000), and Kızılkaya *et al.* (2004) found that the estimated difference between sexes for the parameter K was significant in Japanese quails, but Anthony *et al.* (1986; 1991) reported a non-significant sex effect on parameter K. A significant ($P < 0.05$) divergent selection effect for the K parameter estimate was determined on the difference between HL line and the CL line, and between the LL and CL lines for males. However, there was no significant difference between selection groups and CL line in females.

As seen in Table 2, there were significant sex differences in age and weights at POI within the selection and control lines ($P < 0.05$). Results in this study showed that females reached the POI about four days later than males. Du Preez & Sales (1997) reported that this delay was likely to arise from the greater asymptotic value and consequently the longer acceleration phases in the growth curves. Therefore, weight at POI and mature weight of females were higher than of males. Similar results were reported by Akbaş & Oğuz (1998), Akbaş & Yaylak (2000), Aggrey *et al.* (2003) and Kızılkaya *et al.* (2004). In this study, fixed growth shapes with POI were about 37% of asymptote for the Gompertz model. Divergent selection for 5-week body weight affected age at POI in males, but not in females. However, it affected weight at POI in both sexes. A similar result was reported by Aggrey *et al.* (2003). Although age at maximum growth was approximately the same in the selection and control lines for the females, a significant age difference was found for the males.

Conclusion

The results from this study indicate that response to divergent selection in the linear part (5-week body weight) of the growth curve is evident in the growth pattern of quails. Short-term selection resulted in asymmetric response in divergent lines. Its effect was different in females and males. Growth or different periods of growth, such as developmental or maturation periods, in divergent lines may be controlled by different genes or their effect may be altered under the pressure of selection by sex. Therefore, body weight in the divergently selected lines could be considered as different traits.

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