Relationships of Circulating Concentrations of Insulin-like Growth Factor (IGF)-I and -II to Egg Production and Growth Rate in the Korean Native Ogol Chicken**

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ABSTRACT : Insulin-like Growth Factors (IGFs) and IGF-binding protein act as intra-ovarian regulators that modulate the proliferation and differentiation of the granulosa and theca cells. Moreover, the IGF system is involved in metabolism by modulating the synthesis and degradation of glycogen and protein in animals. However the effect of the IGF system on egg productivity or body growth in KNOC has not been studied in depth. Therefore, this study was performed to investigate differences of serum IGFs and binding protein expressions between two groups showing high and low egg production or body weight and to elucidate the relationship of IGFs with egg productivity and body growth. KNOCs were divided into high and low groups depending on their egg productivity or body growth, and sera were collected every 10 wk from 20 till 60 wk. Serum IGF-I and -II concentration were measured by RIA using human and mouse antiserum and chicken standards. IGFBP was detected by Western ligand blotting. IGF-I concentrations were significantly greater in the high egg production group compared with those in the low egg production group (30 wk, $p<0.01$; 20 and 40 wk, $p<0.05$). Also, differences in IGF-II amounts between the two groups were detected at 60 wk ($p<0.05$). But IGFBPs in the low egg production group were more intense than that in the high egg production group through the egg laying period. The correlation between IGF-I concentration and number of egg production is significantly positive (20 wk, $r=0.2729$: $p<0.05$; 40 wk, $r=0.3500$: $p<0.01$), while IGF-II shows no correlation with egg productivity. In male KNOC, IGF-I and -II concentrations in the high body weight group are lower than that in the low body weight group. Body weight also shows a negative correlation with the serum IGF-II concentration in male chickens (20 wk, $r=-0.5901$: $p<0.01$). Consequently, we suggest that IGFs and binding protein are (in)directly involved in the egg productivity and body growth in KNOC. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 4 : 481-488)***

Key Words : IGF, IGFBPs, Egg Productivity, Body Growth, Korean Native Ogol Chicken

INTRODUCTION

The Korean Native Ogol Chicken (KNOC) is a protected species by Korean government (Protected Species Act No. 265). The number of egg production and average egg weight is about 163 ea and 47.8 g during the egg laying period, and body weight is 1,975.2 g at 44 wk of KNOC (Han et al., 1986). Although the egg productivity and body weight of KNOC are lower than those of commercial chickens, the economic traits of KNOC have been studied by statistical and genetic approaches for selection as layers or broilers (Lee et al., 1995; Seo et al., 1995; Han et al., 1988). Recently, Seo et al. (2001) reported the relationship of IGF-I genotype to body weight and IGF-I concentration of KNOC and Kang et al. (2001) studied the association of steroid hormones with economic traits of KNOC. These two reports indirectly indicated the possibility of improvement in egg productivity and body weight in KNOC using measurement of the endocrine factor expression.

Insulin-like growth factor-I (IGF-I) is a 7.5 kDa, nonglycoprotein that influences the uterus, embryo, and ovary in mammals (Jones and Clemmons, 1995). Although the chicken IGF-I (7 kDa) is different from human, porcine, and bovine IGF-I in eight amino acids, it is composed of 70 amino acids and the function of chicken IGF- I is similar to those other IGF-I (Ballard et al., 1990; McMurtry et al., 1997). In the ovary, IGF-I synergized with FSH and estrogen enhances aromatase activity, progesterone production, and the acquisition of the LH receptor in granulosa cells (Erickson et al., 1989; Giudice et al., 1992). Like mammals, chicken IGF-I also stimulates proliferation and steroidogenesis of granulosa and theca cells (Onagbesan and Peddie, 1995; Roberts and Gordon, 1995). In particular, IGF-I interacts with LH in stimulating [^{3}H] thymidine incorporation into DNA and progesterone production by granulosa cells (Roberts et al., 1994; Onagbesan and Peddie, 1995). IGF-II, a single-chain polypeptide of 67 amino acids, also participates in processes occurring in the theca-interstitial androgen-producing compartment (Giudice, 1992) and the IGF-II variant would be a major determinant of follicular fate (Armstrong and Hogg, 1996). Consequently, these interactions of IGFs and hormones regulate the hierarchical development of granulosa and theca cells.

Actions of IGFs are stimulated or inhibited by IGF binding protein (IGFBP). In mammals, IGFBP plays major roles in modulating the biological actions of the IGFs, including follicular growth and differentiation,

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steroidogenesis, and artresia (Ui et al., 1989; Monget et al., 1993). Other studies (Allander et al., 1995; Schoen et al., 1995) confirmed that the IGFBP-2 and -5 gene were expressed in theca and granulosa cell and suggested that the avian ovaries may be producing IGFBPs that modulate the actions of locally produced IGFs. Reports about the effects of IGF-I and -II on ovaries suggest that IGFs act as intra-ovarian regulators that modulate development and steroidogenesis of the granulosa and theca cell in pre-ovulatory follicles.

In myoblasts, the IGFs have been shown to promote both proliferation and differentiation (Florini et al., 1996). Vandenburgh et al. (1991) demonstrated that IGF-I stimulated myofiber hypertrophy and increased myofiber diameter, which paralleled increase in protein synthesis. During skeletal muscle regeneration, IGF-II involved in the terminal differentiation of proliferating muscle precursor cells (MacGregor and Parkhouse, 1996). Especially, a high correlation between circulating IGF-I and relative growth rate in broiler was detected (McGuinness and Cogburn, 1990). These results support the report that IGF-I may be important in controlling the growth and efficiency of food utilization of young chickens at least in part by modulating the rates of proteins breakdown (Tomas et al., 1998).

To understand the effect of the IGF system on egg productivity and body growth, this study investigated serum IGFs and binding protein expressions between two groups showing high and low egg production or body weight and elucidated the relationships of IGFs with egg productivity and body growth in KNOC.

MATERIALS AND METHODS

Animals

Seventy female and nineteen male Korean Native Ogol Chicken (KNOC) aged 20 wk were housed through 60 wk and reared in individual cages under a photoperiod of 15 h light: 9 h dark at 17 wk. The set-up lighting system was conducted up to17 h light: 7 h dark with a 15 min light increase every week (Ohh, 1988). The KNOCs were fed a commercial diet (16.0% crude protein, 3.0% crude fat, 7.0% crude fiber, 15.0% crude ash, 3.0% calcium, 0.45% phosphate, 0.58% methionine+cystein, 2.75 Mcal/kg metabolizable energy). Water was freely accessible. The number of egg production and egg weight were recorded daily for each hen. Body weight was measured and blood samples obtained from a wing vein were collected from 20 through 60 by 10 wk intervals at 1,100-1,500. Blood was allowed to clot for 1 to 2 h at room temperature, and serum was collected following centrifugation at 1,000×g for 15 min, and stored at -20°C.

IGF-I and -II radioimmunoassay (RIA)

Recombinant chicken IGF-I and -II (GroPep, Pty Ltd., Australia) was iodinated to specific activity of 200-250 μCi/μg by the chloramine T method (Lee and Henricks, 1990). Iodinated IGFs were purified on a sephadex G-50 column and aliquots were stored at -20°C until used.

Serum concentrations of IGF-I and -II were determined by RIA (Daughaday et al., 1980) with minor modifications. The assay employed anti-human IGF-I polyclonal antiserum (GroPep, Pty Ltd., Australia) or anti-mouse IGF-II monoclonal antiserum (Upstate Biotech Inc., US). The intra- and inter-assay of IGF-I were 9.0% and 13.4%, and the assay in IGF-II had an intra-assay variance of 7.5% and inter-assay variance of 14.7%.

Western ligand blotting

Western ligand blotting was performed following the procedure of Hossenlopp et al (1986) as previously decribed (Yun et al., 2000). Briefly, samples pooled by each periods were heated with a 2×nonreducing sample buffer and subjected to SDS-PAGE on gels consisting of a 5% stacking gel and a 12.5% separating gel in electrophoresis buffer (25 mM Tris, 192 mM glycine, 0.1% SDS; pH 8.3). Separated proteins were electrically transferred onto a nitrocellulose membrane in the presence of transfer buffer (25 mM Tris, 192 mM glycine, 20% methanol; pH 8.3). After transfer, the membrane was dried and rinsed with TBS (0.01 M Tris, 0.15 M NaCl, 0.05% NaN_3; pH 7.4). The rinsed membrane was then incubated with 1% non-fat dry milk in TBS and washed with TBS-0.1% Tween-20. The membrane was incubated for 5 hrs at room temperature with TBS-0.1% Tween-20, 1% BSA, and 0.5 to 1.0×10^6 cpm [^{125}I] cIGF-I, was then rinsed two times in TBS-0.1% Tween-20 and 0.1% TBS, dried and exposed to Kodak X-Omat AR film at -80°C for 7 d. A scanning densitometry (MultiImage^{TM}Light Cabinet, Alpha Imager 2200, Alpha Innotech Co.) of the autoradiograph was used to obtain relative IGFBPs levels.

Statistical Analysis

The number of egg production, egg weight, body weight, IGF-I, -II concentrations from high and low groups were statistically analyzed using the Duncan method of the One Way ANOVA procedure and Pearson's correlation coefficients of Statistical Analysis System package (1995).

RESULTS

Comparison of number of egg production and egg weight between high and low egg production groups

The number of egg production : Egg production in KNOC from 20 to 60 wks is described in Table 1A. Egg production started late in 20 wk and peaked at 31-40 wks,

Table 1. Comparisons of (A) number of egg production and (B) egg weight between high and low egg production groups in female KNOC

A. The number of egg production[1)]						
	No. of egg production (ea)					
	0-20 wk	21-30 wk	31-40 wk	41-50 wk	51-60 wk	Total
High group (n=21)	0	17.3±1.4[a]	47.5±0.9[a]	46.1±1.1[a]	38.2±1.5[a]	149.0±2.2[a]
Low group (n=20)	0	5.6±1.4[b]	23.1±3.2[b]	18.6±3.3[b]	11.4±2.7[b]	58.5±5.8[b]
Total (n=70)	0	11.4±1.0	37.6±1.6	34.8±1.9	26.1±1.7	109.9±4.1
B. Egg weight[1)]						
	Egg weight (g)					
	0-20 wk	21-30 wk	31-40 wk	41-50 wk	51-60 wk	Total
High group (n=21)	-	44.3±2.5	48.8±2.0	50.7±2.4	49.0±2.9	48.2±2.0
Low group (n=20)	-	43.7±2.4	48.5±2.4	50.2±3.1	49.7±2.5	47.7±2.2
Total (n=70)	-	43.7±4.0	48.6±2.9	50.5±2.7	48.8±3.6	48.0±2.8

[1)] All values are expressed as mean±SE.

[a,b] Means±SE within a column with different superscripts differ ($p<0.01$).

and this level was maintained until 50 wk. The total number of egg production up to 60 wk is 109.9±4.1 and this result is similar to previous reports (Han et al., 1986; Nahm et al., 1997; Kang et al., 2001). The KNOCs were divided into two groups depending on their egg productivity during the experimental period from 20 wk to 60 wk. The two groups showing high or low egg production comprise the upper and lower 30% of the unselected group, respectively (a high egg production group with higher than 135, average number of egg production is 128.6±2.2; a low egg production group with less than 94, average number of egg production is 51.9±5.8). The number of egg production in the high group show about 2 to 3.5 folds higher throughout the egg laying period. Also, while the number of egg production in plateued at 31 to 50 wks, similar to the pattern in total KNOCs, the low group showed the peak of number of egg production at 31-40 wks and rapidly declined untill 60 wk.

Egg weight : Table 1B shows the comparison of egg weight between the high and low egg production KNOC groups. Similar to the change in egg production, the egg weight of KNOC gradually increased from 21 untill 50 wk, and then decreased by 60 wk. But a difference in average egg weight between the high and low egg production groups was not detected.

Comparison of serum IGF-I, IGF-II, and IGFBP expressions between high and low egg production groups

Serum IGF-I concentration : The concentration of serum IGF-I in high and low egg production groups from 20 till 60 wk are shown in Table 2A. In general, serum IGF-I expression in KNOC was maintained at high level during the early egg laying period (from 20 to 40 wk) and rapidly decreased by 50 wk. With an exception at 20 wk, these results are similar to the change in egg production. Also, like the comparisons of number of egg production between two groups (Table 1A), the high egg production group showed higher levels of IGF-I than the low egg production group during the whole period. Significant differences ($p<0.05$) in IGF-I amounts between the high and low egg production groups were detected at 20 wk (37.0 vs 30.6 ng/ml) and 40 wk (37.7 vs 32.8 ng/ml). Especially, the

Table 2. Comparisons of serum (A) IGF-I and (B) -II concentrations between high and low egg production groups in female KNOC by radioimmunoassay for chicken IGF-I and -II equivalents in acid/ ethanol-extracted serum samples

A. Serum IGF-I concentration[1)]					
	Serum IGF-I concentration (ng/ml)				
	20 wk	30 wk	40 wk	50 wk	60 wk
High group (n=21)	37.0±1.8[a]	36.4±1.8[c]	37.7±1.7[a]	27.4±3.0	24.7±2.6
Low group (n=20)	30.6±2.4[b]	30.4±1.7[d]	32.8±1.9[b]	25.9±4.1	23.2±2.5
Total (n=70)	34.3±1.3	33.4±0.9	36.1±1.0	25.5±1.7	23.8±1.4
B. Serum IGF-II concentration[1)]					
	Serum IGF-II concentration (ng/ml)				
	20 wk	30 wk	40 wk	50 wk	60 wk
High group (n=21)	23.0±1.4	32.1±2.5	39.6±1.8	36.0±1.6	44.6±3.5[a]
Low group (n=20)	28.9±5.5	34.7±4.0	35.1±2.5	39.7±3.3	33.3±4.0[b]
Total (n=70)	26.1±1.9	32.5±1.8	38.9±2.0	36.2±1.1	39.4±1.9

[1)] All values are expressed as mean±SE

[a,b] Means±SE within a column with different superscripts differ ($p<0.05$).

[c,d] Means±SE within a column with different superscripts differ ($p<0.01$).

mean serum IGF-I concentration showed the most significant differences between the high and low egg production groups at 30 wk (36.4±1.8 ng/ml and 30.4±1.7 ng/ml; $p<0.01$) showing the peak of egg production in KNOC.

Serum IGF-II concentration : Contrary to the IGF-I profile, serum IGF-II expression in KNOC gradually increased until 40 wk and was maintained at a high level during the laying period (Table 2B). When serum IGF-II concentration was compared between high and low egg production groups, a significant difference in IGF-II concentration was detected only at 60 wk (high group: 44.6 ±3.5 ng/ml, low group: 33.3±4.0 ng/ml; $p<0.05$). So this result may suggest that serum IGF-II be involved in late egg production, but not in sexual maturity or early egg production in KNOC

Serum IGFBP expression : The expression of IGFBP between the high and low egg production groups from 20 till 60 wk by Western ligand blotting is shown in Figure 1. Although the weak expression of IGFBPs was detected, 40, 34, and 28 kDa IGFBPs were expressed in KNOC, like the previous reports (Armstrong et al., 1989; Bruggeman et al., 1997). Similar to the changes in IGF-I concentration, the IGFBP expressions in both groups gradually increased from 20 till 60 wk. Although significant differences in IGFBP expression between the two groups were not detected, the expressions of 40 and 34 kDa IGFBPs in the low egg production group were more intense than those in the high egg production group during the egg laying periods.

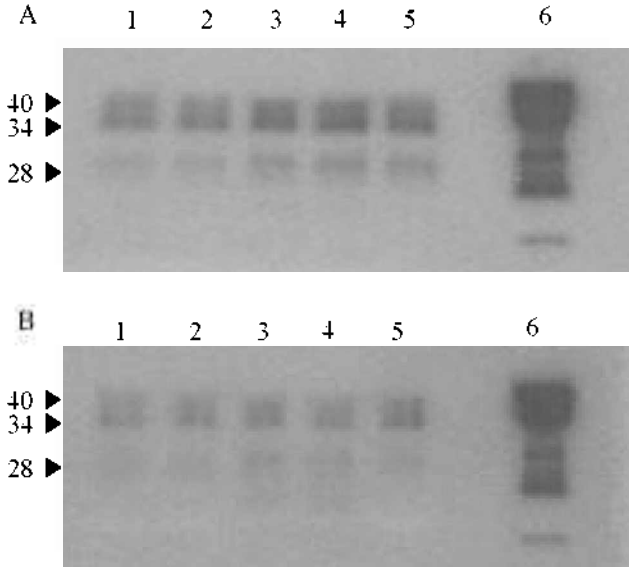

Figure 1. Representative autoradiogram of Western ligand blotting for IGFBP. For each line, 1 μl of pooled porcine serum (control) and a pooled KNOC serum (n=3) in high (A) and low (B) egg production groups from 20 to 60 wk. IGFBPs were separated by nonreduced 12.5% SDS-PAGE, then transferred to nitrocellulose. Membranes were probed with [^{125}I] cIGF-I before autoradiography at -80°C with enhanced screens. Line 1: 20 wk, line 2: 30 wk, line 3: 40 wk, line 4: 50 wk, and line 6: control.

Correlation of serum IGF-I and -II with egg productivity in female KNOC

Table 3 shows correlation coefficients among the serum IGF-I (A), IGF-II (B), and egg productivity including number of egg production, egg weight, and sexual maturity in KNOC. During the early egg laying period showing the highest number of egg production, the correlation between serum IGF-I concentration and egg production was significant (20 wk, $r=0.2729$; $p<0.05$; 40 wk, $r=0.3500$; $p<0.01$). As the egg laying period progressed, the correlation between IGF-I and egg weight increased from $r=-0.1415$ at 20 wk to $r=0.2411$ at 60 wk. Also, sexual maturity and serum IGF-I concentration showed a negative correlation (30 wk, $r=-0.2578$; $p<0.05$). But the correlation between serum IGF-II concentration and egg productivity was not detected during the other periods (Table 3B). These results indirectly suggest that serum IGF-I rather than IGF-II is involved in the egg productivity of KNOC.

Comparison of body weight and relative growth rate between high and low body weight groups

In general, the body weight and relative growth rate (RGR) of male KNOC gradually increased as chicks grew and declined at 60 wk (Table 4). Like the groupings by egg production (Table 1), KNOC were divided into two groups showing high or low body weights. The two groups comprised the upper and lower 30% of KNOC, depending on their body weights at 50 wk in which KNOC has the heaviest average body weight. The body weight in the high group is significantly heavier than that in the low group during whole experimental period, while the decline of RGR in the high group is faster than that in the low group. These results indirectly suggest that the body growth pattern

Table 3. Correlation coefficients of serum (A) IGF-I and (B) IGF-II with egg productivity in female KNOC

A. IGF-I					
	IGF-I				
	20 wk	30 wk	40 wk	50 wk	60 wk
NEP[1]	-	0.2729*	0.3500**	-0.0309	0.2306
EW[2]	-	-0.1415	-0.0571	0.0159	0.2411*
SM[3]	-0.0289	-0.2578*	-	-	-
B. IGF-II					
	IGF-II				
	20 wk	30 wk	40 wk	50 wk	60 wk
NEP[1]	-	-0.0034	0.0943	0.1885	0.1693
EW[2]	-	0.1803	0.0180	-0.0551	0.0369
SM[3]	-0.0718	0.0067	-	-	-

[1] Number of egg production.
[2] Egg weight.
[3] Sexual maturity.
* $p<0.05$; ** $p<0.01$.

Table 4. Comparisons of (A) body weight and (B) relative growth rate between high and low body weight groups in male KNOC

A. Body weight[1)]					
	Body weight (g)				
	20 wk	30 wk	40 wk	50 wk	60 wk
High group (n=6)	1,750.0±47.4[a]	2,033.8±50.0[a]	2,183.0±60.0[a]	2,287.0±41.1[a]	2,108.1±51.6[a]
Low group (n=6)	1,360.0±53.8[b]	1,506.2±80.5[b]	1,652.3±62.4[b]	1,716.7±47.6[b]	1,718.5±51.7[b]
Total (n=18)	1,544.1±46.3	1,771.5±60.2	1,896.3±59.8	1,979.4±60.9	1,892.0±47.2
B. Relative growth rate[1)]					
	Relative growth rate (%)[2)]				
	20-30 wk	30-40 wk	40-50 wk	50-60 wk	
High group (n=6)	13.7	6.8	4.6	-8.6	
Low group (n=6)	9.1	9.0	3.8	0.1	
Total (n=18)	12.3	6.7	4.2	-4.4	

[1)] All values are expressed as mean±SE.

[2)] Relative growth rate=$(W_2-W_1) / W_1 \times 100$. where W_1 is the first measurement and W_2 is the second measurement.

[a,b] Means±SE within a column with different superscripts differ ($p<0.01$).

between high and low body weight groups differ.

Comparison of serum IGF-I and -II expressions between high and low weight groups

The male KNOC showed the highest IGF-I concentration at 20 wk in which the highest RGR was detected, and then IGF-I concentration moderately declined (Table 5A). In contrast to the IGF-I concentration, the IGF-II concentration of the male KNOC at 20 wk was the lowest and rapidly increased until 40 wk (Table 5B). Generally, IGF-I and -II concentrations in the high body weight group are lower than those in the low body weight group. Especially, significant differences in IGF-I and -II concentrations between the two groups were detected at 20 wk (IGF-I: 45.8 vs 54.9 ng/ml; IGF-II: 14.7 vs 22.8 ng/ml; $p<0.05$). This result indirectly suggests that serum IGFs may be involved in the body growth or growth rate of male KNOC.

Correlation of serum IGF-I and -II with growth in male KNOC

Correlation coefficients of serum IGF-I (A) and -II (B) with growth (body weight and RGR) in KNOC are shown in Table 6. Correlation of IGF-I with RGR was positive at 40 wk ($r=0.5349$: $p<0.05$), while body weight had a negative correlation with serum IGF-II concentration (20 wk, $r=-0.5901$: $p<0.01$; 30 wk, $r=-0.5000$: $p<0.05$).

DISCUSSION

In the present study, we investigated the expressions of IGF-I, -II, and binding proteins between two groups showing high and low egg production or body weight for elucidation of the relationship among IGF system, egg productivity, and body growth in KNOC.

In chicken, the egg productivity is comprised of the number of egg production, egg weight, and sexual maturity. The number of matured follicle selected for ovulation, the successive hierarchy of developing follicle, and the capacity of the oviduct are very important factors in the egg production. Among others, the proliferation and differentiation of follicles are affected by IGF-I (Onagbesan et al., 1999). IGF-I stimulates both proliferation and progesterone production in granulosa cells by modulating

Table 5. Comparisons of serum (A) IGF-I and (B) -II concentrations between high and low body weight groups in male KNOC by radioimmunoassay for chicken IGF-I and -II equivalents in acid/ ethanol-extracted serum samples

A. Serum IGF-I concentration[1)]					
	Serum IGF-I concentration (ng/ml)				
	20 wk	30 wk	40 wk	50 wk	60 wk
High group (n=6)	45.8±1.9[a]	30.0±3.3	25.8±3.3	21.9±1.4	25.5±3.3
Low group (n=6)	54.9±3.7[b]	36.7±3.6	27.9±1.2	29.3±4.3	28.1±2.3
Total (n=18)	47.2±2.1	31.3±1.9	25.5±1.4	25.4±1.7	27.6±1.7
B. Serum IGF-II concentration[1)]					
	Serum IGF-II concentration (ng/ml)				
	20 wk	30 wk	40 wk	50 wk	60 wk
High group (n=6)	14.7±1.9[a]	30.0±3.3	26.7±2.0	20.7±4.2	21.4±3.0
Low group (n=6)	22.8±2.1[b]	36.7±3.6	30.5±2.4	17.1±2.1	18.8±1.7
Total (n=18)	19.5±1.6	31.3±1.9	28.3±1.6	19.7±1.9	19.9±1.3

[1)] All values are expressed as mean±SE.

[a,b] Means±SE within a column with different superscripts differ ($p<0.05$).

Table 6. Correlation coefficients of serum (A) IGF-I and (B)-II with in male KNOC

A. IGF-I					
	IGF-I				
	20 wk	30 wk	40 wk	50 wk	60 wk
BW[1]	-0.2567	-0.2787	0.1437	-0.4041	-0.2042
RGR[2]	-	-0.0749	0.5349*	0.3416	-0.0972
B. IGF-II					
	IGF-II				
	20 wk	30 wk	40 wk	50 wk	60 wk
BW[1]	-0.5901**	-0.5000*	0.1179	0.3405	0.0071
RGR[2]	-	-0.2601	0.2404	-0.4630	-0.3662

[1] Body weight.
[2] Relative growth rate.
* $p<0.05$; ** $p<0.01$.

P450scc and 3β-hydroxysteroid dehydrogenase expression (Onagbesan et al., 1994; Onagbesan and Peddie, 1995) and FSH-stimulated cAMP accumulation (Adashi et al., 1986). For ovulation, IGF-I also synergizes with FSH so that it stimulats the synthesis of LH receptor (Adashi et al., 1985b) and aromatase activity (Adashi et al., 1985a). These imply that IGF-I may play important roles in the egg production, which is supported by the present study.

As shown in Table 2, IGF-I concentration in the high egg production group is significantly higher than that in the low egg production group during the early egg production periods (36.4±1.8 ng/ml and 30.4±1.7 ng/ml; $p<0.01$). This different expression may increase the synthesis of progesterone and responsiveness to gonadotropin in granulosa or theca cells. The increase of progesterone may then precede and stimulate the LH rise, and the presence of a positive feedback between progesterone and LH could result in hormone peaks that induce ovulation (Johnson et al., 1984). Therefore, although the low correlation of serum IGF-I expression with the number of egg production was detected (Table 3A), it is likely that IGF-I in blood positively affects the complex mechanism of follicle maturation and ovulation in KNOC. Under the scanty information about the effects of IGFs on egg productivity in chicken, these results are thought to be important in the possibility of IGF-I as an indicator to increase up the egg production. Also, significant differences in IGF-II concentration between high and low egg production groups were detected at 60 wk (Table 2B). This could be explained by the observation that IGF-II variants were expressed only in follicles at the time they were recruited into the follicular hierarchy and would be a major determinant of follicular fate, as reported by Armstrong and Hogg (1996). Although the IGF-II action in avian reproduction has been poorly understood, recent studies have investigated the effects of IGF-II on the intraovarian control of ovarian function. Onagbesan et al. (1999) reported that IGF-II, similar to IGF-I, enhances progesterone and androstenedione production by granulosa and theca cells. But this response is most likely mediated via the type I IGF receptor because a Type II IGF receptor has not been reported in avian ovarian tissue (Roberts et al., 1994).

In mammals, IGFBPs function as a transporter, prolong the half-life of IGFs, provide the tissue- and cell type-specific localization of IGFs, directly regulate receptor binding, and affect cellular functions independent of IGFs (Furlanetto, 1980; Zapf et al., 1984; Jones and Clemmons, 1995; Hwa et al., 1999). Above all, IGFBPs play a major role in regulating the biological activity of the IGFs, including modulation of steroidogenesis and follicular growth (Ui et al., 1989; Monget et al., 1993). This present study showing the higher expression of 40, 34, and 28 kDa IGFBPs in the low egg production group than that in the high egg production group conflicts with the previous study showing that altered IGFBP profiles may contribute to the depressed proliferation and steroidogenesis observed *in vivo* in granulosa cells of atretic follicles (Monget et al., 1993). The differences in IGFBP expression between the two groups can affect IGF-I or –II action for the development of follicles and ovaries and the number of egg production, accordingly. Therefore, it is suggested that the profiles of IGFs and binding protein expression may decide the egg production by modulating the proliferation and differentiation (steroidogenesis) of granulosa and theca cells in KNOC.

In addition to the effect of IGFs on egg production, IGFs also function as modulator of metabolism such as transport of glucose and amino acids, synthesis of glycogen and protein, and inhibition of proteolysis (Nissley and Rechler, 1984; Gluckman et al., 1991; Jones and Clemmons, 1995). Especially, the correlation between plasma IGF-I concentration and growth traits is generally positive in humans (Reece et al., 1994; Yang and Yu, 2000), calfs (Lee et al., 1995), and mice (Blair et al., 1987). In poultry, however, studies regarding the relationship between circulating IGF-I and posthatch growth have shown variable results. Scanes et al. (1989) suggested that plasma IGF-I concentration was greater in genetic lines selected for high growth rate compared to that in slower growing lines. In contrast, selection for increased growth rate in broilers resulted in depressed IGF-I synthesis and secretion (Huybrechts et al., 1985; Pym et al., 1991). As in previous reports, the present study showed that serum IGF-I and –II expressions in the low body weight group were higher than those in the high body weight group (Table 6). However, serum IGF-II concentration has a negative correlation with body weight in male KNOC (20 wk, r=-0.5901; 30 wk, r= -0.5000), while the correlation between IGF-I and RGR is positive (40 wk, r=0.5349). These opposite results could be considered that body growth in poultry is dependent on not only IGFs but also nutrition, sex, time, and species.

Therefore, for an exact understanding of IGF effect on KNOC body growth, several other studies should be carried out in parallel.

In summary, the present study has investigated the association of IGFs and binding protein with egg productivity and body weight in KNOC. Although elucidation of the exact action of IGFs in the body growth of KNOC requires more studies, different expressions of IGF-I and IGF-II between the high and low egg productivity groups during the egg laying period indicate their regulating roles in ovulation or egg production. Consequently, this study supports hypothesis that IGFs and IGFBP act as intra-ovarian regulators that modulate the growth and differentiation of granulosa and theca cells in pre-ovulatory follicles and suggests the possibility of IGFs as indicators for egg productivity in KNOC.

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