Estimation of Growth Curve Parameters for Body Weight and Measurements in Castrated Hanwoo (*Bostaurus Coreanae*)

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한우 거세우의 체중 및 체형에 대한 성장곡선 모수 추정

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요 약

본 연구는 한우의 체형과 체중이 일령에 따라 어떻게 변화하며, 선발형질인 도체형질과의 상관 또한 체중 및 체형의 변화에 따라 어떠한 형태로 변화하는지 알아보기 위하여 실시하였다. 분석에 이용한 형질은 체중, 체형 및 도체형질을 포함하여 모두 17가지 형질이며 거세우 161두의 자료를 이용하였다. 성장곡선 추정은 logistic 모형을 이용하였고, 추정한 모수를 토대로 변곡일령 및 변곡일령에서의 특성을 다시 계산하였다. 각 형질에 대한 성장곡선 모수를 분석한 결과 좌골폭은 조숙성, 흉위는 만숙성 형질인 것으로 나타났다. 등지방두께에 대한 흉심, 흉폭 및 요각폭의 순위상관계수는 6~24개월까지 꾸준히 증가하는 반면 다른 체형형질들은 18개월령 이후에 감소하는 것으로 나타났다. 본 연구는 표현형 자료에 대한 분석만이 이뤄졌으나, 한우 성장 단계에 따른 유전적 변화를 살펴보기 위해 유전모수 추정과 같은 추가적인 연구가 이뤄진다면 체형형질을 한우개량에 충분히 이용이 가능할 것으로 생각된다.

(**Key words :** Growth curve, Logistic model, Body measurement, Castrated hanwoo)

Ⅰ. INTRODUCTION

The skeleton and weight of animals have biological characteristics that change together with the age of the individual organism (Lee, 2003c). The data used to study the infinite changes over time are temporary data measured at specific times and places. However, in order to study the biological characteristics of animals, all changes over time must be measured successively. But it is not easy to measure the continuously changing weight and body shape of animals in tune with all time variables (Kratochvílová et al., 2002; Lopez de Torre et al., 1992). Moreover, these longditudinal data (Fitzhugh, 1976) change in a non-linear rather than linear pattern, and this non-linear pattern develops into a sigmoid pattern. The most used models to describe growth patterns in beef cattle are Brody, Bertalanfy, logistic, Gompertz and Ricards (Arango and Van

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Vleck, 2002; Brown et al., 1976; Fitzhugh, 1976; Johnson et al., 1990). Among them, the logistic model was used for the estimation of the weight and body shape growth curves of castrated Hanwoo in this study.

Hanwoo is a Korean native breed of cattle, which is a hybrid of Indian cattle (*Bos indicus*) and European cattle (*Bos primingenius*) appearing in about 2,000 BC. It adapts well to environmental and breeding conditions and has a docile nature. However, its mature weight is lower than other beef breeds and the time for reaching mature weight is slower (Lee et al., 2003a). The Hanwoo national improvement program in Korea began in earnest with the introduction of performance test in 1982 and progeny test in 1987. At present all the cattle for progeny test are castrated before 6 months of age and reared upto 24 months of age when the carcass test is performed to select proven bulls. For the progeny testing of cattle, their weight, body shape and carcass traits are investigated from 6 months of age until slaughter. Since only the carcass traits are examined for ranking, weight and body shape are not considered in selection at all, and these data are not widely used. Nevertheless, there have been some studies on weight because it relates to economic traits. There have also been studies on the estimation of the growth curve (Cho, 2000; Cho et al., 2002; Cho et al., 2006; Kim et al., 2002; Lee et al., 2003a; Lee et al., 2003b; Lee et al., 2003c). However, the average frequncy for the body measurement of Hanwoo between 6 and 24 months of age is only about three, and there has been no research on the growth curve of body measurements in castrated Hanwoo.

This study was conducted to figure out how the shape of Hanwoo changes over time, examine the rank correlations between the carcass traits which are the selection traits and parameters of growth curve, and determine the correlation between body shape and carcass. It is expected that the result of this study will provide data to determine whether weight and body shape of castrated Hanwoo can contribute to the selection of proven bulls.

Ⅱ. MATERIALS AND METHODS

1. Source of Data

For this study, castrated Hanwoo records were collected in 1998~2006 and records that investigation frequency was less than seven times were excluded to analyze. Body weights and measurements collected after castration (before 6 months) to slaughter (24 months), and the carcass traits measured at slaughter were used for analysis. Weights, body measurements and carcass traits were measured from 161 castrated Hanwoo, and 12 physical traits and 5 carcass traits were investigated in total. The physical traits measured at each part indicated in Fig. 1. include body height (BH), rump height (RH), body length (BL), chest depth (CHD), chest width (CHW), hip width (HW), thurl width (TW), pinbone width (PW), rump length (RL), chest girth (CHG) and foreshank circumference (FSC). For carcass traits, backfat thickness (BF), longissimus muscle area (LMA), carcass weight (CW), dressing percentage (DP) and marbling score (MS) were examined.

Each carcass trait was measured as follows: BF was measured at the inner point around 2/3 from the backbone at the site of the longissimus muscle area measurement. LMA was measured as muscle area at the final thoracic vertebrae side perpendicular to the vertebra located between the right-left thoracic vertebra and the first lumbar vertebra. CW was measured shortly after slaughter based on both right and left semi-carcass weights and kept at 0~5℃ in cold storage for more than 24 hours. DP was measured and expressed as a ratio of cold carcass weight over live weight

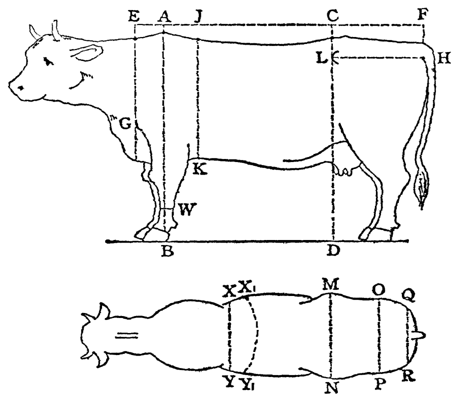

Fig. 1. A part of body measurement.
(A~B) height at wither (BH); (C~D) height at rump (RH); (E~F) horizontal distance between top of shoulder and pins (BL); (J~K) depth at chest (CHD); (X~ Y) width of chest (CHW); (M~N) horizontal distance between top of hips (HW); (O~P) horizontal distance between projecting part of pelvises (TW); (QR) horizontal distance bet- ween pins (PW); (LH) distance in straight line between front of hipbone to pinbone (RL); (X1~Y1) girth of chest (CHG); (W) girth of right ankle (FSC);

before slaughter. MS was measured subjectively as scores of point 1 to 7 according to the standard marbling score (1~7 grades) at the site of longissimus muscle area.

The basic statistics for weight, body measurements, and carcass traits at 6, 12, 18, and 24 months of age from 161 heads are summarized in Table 1. The weight and body measurements at 6, 12, 18, and 24 months of age were adjusted by the following formula:

$$\left(\frac{\text{Observation at } X_2 \text{ ages - observation at } X_1 \text{ ages}}{X_2 \text{ ages - } X_1 \text{ ages}}\right)$$

$$\times 30.5 \times 6,\ 12,\ 18,\ 24$$

For estimation of the growth curve, the weight was not adjuested by the above formula, while the body measurements at 6 to 24 months were adjusted.

2. Statistical Method

The growth curve parameters were estimated by the nonlinear regressive logistic model using PROC NLIN which is the nonlinear regression analysis procedure of SAS (1990). It was estimated by the Multivariate Secant iterative method, often referred to as DUD (Doesn't Use Derivative) method, which does not require the specification of partial derivative. The convert-gence criterion for estimation is as follows:

$$(SSE_{i-1}\text{-}SSE_i)/(SSE_i+10^{-8})<10^{-10}$$

Where, SSEi is the sum of square error at i^{th} iteration.

At model selection procedure for estimation of growth curve about body weight and body measurements in Hanwoo, 3 growth curve functions such as Gompertz, logistic and Von Bertallanffy had been applied. And this research did not show the result, logistic model showed the smallest residual mean squares among 3 models and used logistic model in this study. The logistic model (Nelder, 1961) used for the estimation of growth curve is:

$$Y_t = A\,(1 + be^{-kt})^{-1}$$

Where, Yt is the estimated weight and body measurement at the age of t days, A is the weight and body measurement at $t=\infty$, b is the parameter of growth ratio, k is the maturity rate, e is the natural logarithm, and t is the age in days.

To get the parameter of weight and body measurement at maturity A at $t=\infty$:

MY (mature body weight or body measurements) $= A\,(1/(1 + be^{-\infty})) = A$

To get the growth ratio at $t=0$, *BY* (weight and body measurement at birth) $= MY\,(1 + be^{0})^{-1} = MY\,(1 + b)^{-1.}$ Therefore, $b = (MY/BY)/BY.$

To get the maturity rate at $t = t_i$, $Yt = MY\,(1 + be^{-kt})^{-1}$ and $k = (log_e((Y_t\text{-}MY)/(MY\text{-}BY))t_i)$. Furthermore,

Table 1. Means and their standard errors of body weight, different body measurements and carcass traits

Age (month)	N	Body weight & body measurement traits							
		BW (kg)	BH (cm)	RH (cm)	BL (cm)	CHD (cm)	CHW (cm)	HW (cm)	TW (cm)
6	161	145.3 ±2.5	96.61 ±0.4	99.37 ±0.4	98.85 ±0.7	44.95 ±0.3	25.40 ±0.2	21.77 ±0.2	24.21 ±0.2
12	161	250.7 ±2.9	108.0 ±0.4	110.7 ±0.4	119.3 ±0.5	55.91 ±0.2	32.28 ±0.2	33.14 ±0.2	33.96 ±0.2
18	161	389.7 ±4.2	120.9 ±0.3	124.0 ±0.3	137.5 ±0.5	64.60 ±0.2	39.50 ±0.3	39.70 ±0.2	39.31 ±0.2
24	161	526.1 ±4.6	129.9 ±0.3	133.8 ±0.3	149.4 ±0.5	72.24 ±0.3	46.91 ±0.3	45.57 ±0.2	46.52 ±0.2

Age (month)	N	Body weight & body measurement traits				N	Carcass traits[1]				
		PW (cm)	RL (cm)	CHG (cm)	FSC (cm)		BF (mm)	EMA (cm^2)	CW (kg)	DP (%)	MS[2] (Score)
6	161	10.62 ±0.2	29.61 ±0.3	124.0 ±0.7	14.45 ±0.1	161	6.782 ±0.2	71.86 ±0.7	290.9 ±2.9	69.17 ±0.1	2.795 ±0.1
12	161	19.06 ±0.1	41.60 ±0.2	149.5 ±0.6	16.55 ±0.1						
18	161	23.96 ±0.1	47.43 ±0.2	177.7 ±0.7	18.49 ±0.1						
24	161	25.89 ±0.1	51.79 ±0.2	204.1 ±0.7	19.77 ±0.1						

[1] Animals were slaughtered at 24 months of age.
[2] MS ranged between 1 to 7 according to Korea beef cattle meat grading standard.

the point of inflection at the maximum gradient ($t = t_i$) is $t_i = (1/k)log_e b$, the weight and body measurement at the point of inflection is $Y_{ti} = A$ (1/2), and the growth speed ($\partial Y_i = \partial t_i$) at the point of inflection is $\partial Y_i / \partial t_i = kY_{t_i}(be^{-kt_i} / (1+be)^{-kt_i}$.

The correlations between the parameters *A*, *b* and *k* obtained from estimation of growth curve for each growth trait and carcass traits were analyzed to figure out a correlation between growth characteristics and carcass traits of castrated Hanwoo and a correlation between changes of weight and body measurements over time from 6 to 24 months of age and the carcass traits. For these two correlation analyses, PROC CORR, the correlation analysis procedure of the SAS Package (1990) was used. The correlation of body weight and body measurement at 6 to 24 months of age on carcass traits were analyzed by spearman method.

Ⅲ. RESULTS AND DISCUSSION

1. Estimation of growth curve parameters

The parameters and growth characteristics estimated by the logistic growth curve using the weight and body measurement data from 161 steers are presented in Table 2. First, the parameter A for the weight and body measurements at maturity was 795.6 ± 37.7 kg, 155.5 ± 4.2 cm, 164.9 ± 5.8 cm, 168.5 ± 2.9 cm, 83.5±1.6 cm, 70.0 ± 5.2 cm, 49.5 ± 0.6 cm, 60.7 ± 2.7 cm, 26.8 ± 0.2 cm, 53.2 ± 0.4 cm and 329.6 ± 23.5 cm for weight, body height, rump height, body length, chest depth, chest width, hip width, thurl width, pinbone width, rump length, chest girth and

Table 2. Estimated parameters and growth characteristics at inflection point of the logistic model

Trait	Parameters*				Growth characteristics at inflection point		
	A±SE	*b*±SE	*k*±SE	RMS	Age	Gain	Measurement
BW	795.6 ±37.7	9.42 ±0.28	0.00405 ±0.00017	2,278.8	553.72	0.80	397.8
BH	155.5 ±4.2	0.95 ±0.03	0.00217 ±0.00017	22.65	−24.02	0.08	77.75
RH	164.9 ±5.8	0.99 ±0.04	0.00200 ±0.00017	23.60	−3.51	0.08	82.45
BL	168.5 ±2.9	1.27 ±0.02	0.00317 ±0.00019	52.82	76.56	0.13	84.25
CHD	83.5 ±1.6	1.51 ±0.02	0.00304 ±0.00016	10.77	136.25	0.06	41.75
CHW	70.0 ±5.2	2.80 ±0.20	0.00237 ±0.00020	11.69	434.51	0.04	35.00
HW	49.5 ±0.6	2.39 ±0.06	0.00429 ±0.00017	6.854	202.72	0.05	24.77
TW	60.7 ±2.7	2.03 ±0.08	0.00252 ±0.00018	7.652	281.65	0.03	30.35
PW	26.8 ±0.2	4.04 ±0.19	0.00643 ±0.00021	3.389	217.03	0.04	13.39
RL	53.2 ±0.4	1.77 ±0.06	0.00513 ±0.00020	7.223	111.80	0.06	26.60
CHG	329.6 ±23.5	2.34 ±0.20	0.00184 ±0.00014	78.32	461.24	0.15	164.8
FSC	23.1 ±0.7	0.94 ±0.03	0.00237 ±0.00023	0.93	−26.55	0.01	11.54

* *A* is mature body measurement or body weight; *b* is growth ratio; *k* is maturing rate;
RMS : residual mean squares

fore-shank circumference, respectively. The parameter *b* indicating the growth ratio was 9.42 ± 0.28, 0.95 ± 0.03, 0.99 ± 0.04, 1.27 ± 0.02, 1.51 ± 0.02, 2.80 ± 0.20, 2.39 ± 0.06, 2.03 ± 0.08, 4.04 ± 0.19, 1.77 ± 0.06, 2.34 ± 0.20, and 0.94 ± 0.03, respectively, being greatest for weight. Among body measure-nts, it was greatest for pinbone width and lowest for fore-shank circumference.

The parameter *k* indicating the maturity rate was 0.00405 ± 0.00017, 0.00217 ± 0.00017, 0.00200 ± 0.00017, 0.00317 ± 0.00019, 0.00304 ± 0.00016, 0.00237 ± 0.00020, 0.00429 ± 0.00017, 0.00252 ± 0.00018, 0.00643 ± 0.00021, 0.00513 ± 0.00020, 0.00184 ± 0.00014, and 0.00237 ± 0.00023, respectively. The value of this parameter *k* was greatest for pinbone width, which suggests that it is an early ripening trait, while it was lowest for chest girth, suggesting that it to be a late ripening trait. Kim et al. (2002) reported that the parameters *A*, *b* and *k* estimated for the weight of castrated Hanwoo using the Gompertz model were 823.1, 3.301 and 0.0489, respectively. The results of this study showed that estimated parameters *A* and *k* were lower and the parameter *b* was higher. Furthermore, *A*, *b* and *k* in this study were all greater than those of growth curves reported by Cho (2000) and Lee et al. (2003a) for bulls and cows. The estimated parameters *A*, *b* and *k* for castrated Hanwoo using the logistic model by Cho et al. (2006) were 936.9 ± 51.27, 9.280 ± 0.294 and 0.003 ± 0.0001, respectively.

Growth characteristics at inflection point of the logistic model were shown as Table 2. The weight, body height, rump height, body length, chest depth, chest width, hip width, thurl width, pinbone width, rump length, chest girth, and fore-shank circumference were 553.72 days, −24.02 days, −3.51 days, 76.56 days, 136.25 days, 434.51 days, 202.72 days, 281.65 days, 217.03 days, 111.80 days, 461.24 days and −26.55 days, respectively. The age at the inflection point for weight was about 18 months, which implies that growth rate gradually decreases after 18 months of age. This result differed by about one month from that of Kim et al. (2002) who reported that the relative body weight of steer rapidly decreased to 79.2% until 19.5 months of age, and then increased slowly. The body height and rump height showed a negative ages of inflection. One reason for the negative value seems to be because the age of inflection is $t_i = (1/k)\log_e b$, which is fixed at 50% of the parameter *A*, and the *b* and *k* are b = (*MY/BY*)/*BY* and $k = [\log_e((Y_{t_i} - MY)/(MY - BY))]/t_i$, respectively, so there is no value for t_0. As human beings and many animals are born after a certain degree of growth, the hypothesis that inflection takes place before birth is not totally improbable (Lawrence, 1980). In the progeny testing system currently available in Korea, it is difficult to analyze records before 6 months of age because the collection of records before weaning is not easy. Cho et al. (2002) reported that for the parameters of growth curve for maturity values and maturity rate to be affected less and to improve the accuracy of estimation, the final measurement time must be at least 22 months of age. Cho et al. (2006) also reported that the data volume and specification type must be considered in the estimation in addition to the early data until 6 months of age. The increases of weight and body measurements at the age of inflection were 0.80 kg, 0.08 cm, 0.08 cm, 0.13 cm, 0.06 cm, 0.04 cm, 0.05 cm, 0.03 cm, 0.04 cm, 0.06 cm, 0.15 cm and 0.01 cm, respectively, showing that among the growth traits, body length and chest girth had the greatest degree of growth at the age of inflection. The estimated weight and body measurements at the age of inflection was 397.8 kg, 77.75 cm, 82.45 cm, 84.25 cm, 41.75 cm, 35.00 cm, 24.77 cm, 30.35 cm, 13.39 cm, 26.60 cm, 164.8 cm and 11.54 cm, respectively. Compared to the studies of Lee et al. (2003a) and Cho (2000), the results of our study showed

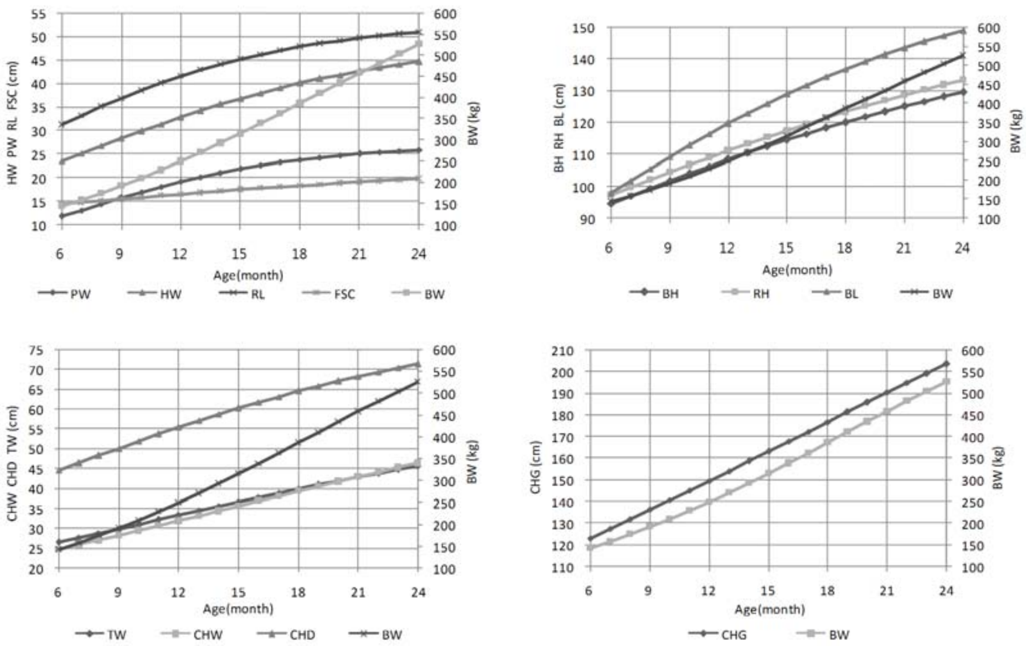

Fig. 2. Growth curves estimated by logistic function of body weight and measurements of castrated Hanwoo.

that the age for reaching the point of inflection and the estimated weight at the point of inflection were lower than those of Hanwoo cows and bulls. Furthermore, compared to the studies of Kim et al. (2000) and Cho et al. (2006) who estimated the growth curve against weight of steer's weight at the point of inflection and the age reaching the point of inflection were higher in this study.

Fig. 2 shows a graph which summarizes the growth curve parameters and growth characteristics described above. It was found that pinbone width and other posterior parts grew faster than other traits, and the chest related traits corresponding to anterior parts grew slower. Moreover, a numerical analysis showed that the growth gradients of body height, rump height, and fore-shank circumference which had a negative age of inflection decreased slowly.

2. Correlation

Joandet and Cartwright (1969), Long et al. (1975), Butts et al. (1980) and Tawah and Franke (1985) reported that estimation of these parameters could be of importance for selection purposes, given their association with other traits and the economy of production. Correlation analysis was carried out to find the correlations between the growth curve parameters *A*, *b* and *k* which were estimated using the logistic growth model and the carcass traits and the results are shown in Table 4. Correlation analysis was performed only for individuals where the individual growth curve was estimated. The carcass traits included backfat thickness, longissimus muscle area, carcass weight, dressing percent, and marbling score. The correlation coefficient between the parameter *A* indicating the estimated value at maturity and the carcass traits

Table 4. Correlation between carcass traits and growth curve parameters of body weight and measurements of castrated hanwoo

Trait	*A*					*b*		
	BF	EMA	CW	DP	MS	BF	EMA	CW
BW (n=127)	0.02	−0.13	0.09	−0.12	−0.14	−0.21*	−0.24**	−0.23**
BH (n=119)	−0.04	−0.12	0.02	−0.04	0.01	−0.28**	−0.33**	−0.38**
RH (n=118)	−0.07	−0.06	0.03	0.01	−0.06	−0.24**	−0.25**	−0.28**
BL (n=119)	−0.05	−0.08	0.04	−0.02	0.01	−0.19*	−0.02	−0.06
CHD (n=81)	0.16	0.05	0.24*	−0.16	−0.07	−0.01	−0.04	−0.06
CHW (n=123)	0.08	0.07	0.15	−0.07	0.10	−0.09	0.10	−0.02
HW (n=138)	0.16	0.16	0.23**	−0.09	0.05	−0.08	−0.12	−0.06
TW (n=111)	0.08	0.03	0.13	−0.08	0.01	−0.08	−0.14	−0.15
PW (n=143)	0.11	0.33**	0.27**	0.04	0.26**	−0.06	−0.35**	−0.20**
RL (n=139)	0.05	0.15	0.30**	−0.02	0.25**	0.00	−0.20*	−0.12
CHG (n=112)	0.04	−0.04	0.10	−0.08	−0.02	−0.08	−0.11	−0.04
FSC (n=112)	−0.01	−0.07	0.07	−0.05	0.07	−0.31**	−0.08	−0.09

Trait	*b*		*k*				
	DP	MS	BF	EMA	CW	DP	MS
BW (n=127)	0.09	−0.13	0.04	0.25**	0.12	0.08	0.13
BH (n=119)	0.14	−0.19**	−0.01	0.07	−0.12	0.08	−0.03
RH (n=118)	0.12	−0.13	0.09	0.06	0.02	−0.04	0.08
BL (n=119)	0.17	0.07	0.05	0.18	0.14	0.03	0.07
CHD (n=81)	0.00	0.31**	0.01	0.03	0.00	0.01	0.22**
CHW (n=123)	0.14	0.06	0.00	0.12	0.02	0.06	0.02
HW (n=138)	0.01	−0.02	−0.01	−0.04	0.03	−0.03	0.00
TW (n=111)	0.02	0.02	−0.01	0.05	−0.07	0.05	0.04
PW (n=143)	−0.11	−0.18*	−0.01	−0.35**	−0.15	−0.16	−0.22**
RL (n=139)	−0.09	−0.03	0.11	−0.07	−0.03	−0.13	−0.11
CHG (n=112)	0.01	−0.05	−0.08	−0.01	−0.11	0.08	−0.04
FSC (n=112)	0.23*	0.03	−0.08	0.13	0.03	0.15	−0.06

** : significant (p<0.01); ns : not significant (p>0.05).

ranged from −0.16 to 0.33. The correlation coefficient between dressing percent and chest depth was the lowest, while the correlation between longissimus muscle area and pinbone width was higher than that of other carcass traits. The parameter *b* indicating the growth ratio ranged from −0.38 and 0.31. The correlation between carcass weight and body height was the lowest, while correlation between marbling score and chest depth was the highest, but correlation coefficients of most other traits were negative. The parameter *k* indicating maturity rate ranged from −0.35 to 0.25. The correlation between marbling score and pinbone width was the lowest, while the correlation between marbling score and weight was higher than that of other carcass traits. The most notable result in Table 4 was that the fastest growth occurred at the posterior parts of Hanwoo such as hip width, thurl width and pinbone width. Furthermore, pinbone width among the posterior parts was found to be an early ripening trait compared to other physical traits in the growth curve parameter estimation. However, the correlation coefficients with the parameter *A* indicating maturity value are higher than those for other traits, and the correlation coefficients between the parameter *k* indicating maturity rate and all carcass traits are negative. Therefore, it is believed that raising the maturity values and lowering the maturity rate of posterior parts will help improve the carcass traits to some degree. On the other hand, the correlation coefficient between chest girth, which showed the lowest maturity rate, and the parameter *A* indicating maturity value, was positive for backfat thickness and carcass weight which are meat volume traits. The correlation coefficients between chest girth and meat quality traits such as longissimus muscle area, dressing percent and marbling score were negative, and the correlation coefficients with the parameter *k* indicating maturity rate were negative for all traits except dressing percent. Therefore, improvement of meat quality might be achieved by slowing down the growth of chest girth and lowering the maturity values as well. Furthermore, Cho (2000) reported that considering the fact that marbling deposition (which is a criterion of meat quality) occurs usually after 12 months of age and the point of inflection occurs later, the marbling score is good. This is because the marbling deposition is active due to the continuous increase in growth rate.

Table 5 shows the results of rank correlation analysis between the weight and physical traits at 6, 12, 18, and 24 months of age and the carcass traits in order to find out how the correlations change while the weight and body shape change over 6 to 24 months of age, and to determine the possibility of early selection of weight and body shape by investigating the rank changes over time. Early selection using the parameters of the growth curve excluded the physical traits other than anterior and posterior parts. The ratios between area, volume, weight and body height of Hanwoo were calculated to analyze their correlations with carcass traits over the change of age. Most traits showed not so high rank correlations with carcass traits, which varied for each carcass trait. First, the rank correlations of chest depth, chest width, and hip width with backfat thickness steadily increased from 6 to 24 months of age, while the rank correlations of other traits decreased after 18 months until 24 months. For pinbone width, the correlation decreased at 12 months of age but increased again after 18 months. The correlation coefficient of chest depth with the longissimus muscle area steadily increased until 24 months and that of hip width and pinbone width decreased at 12 months but increased again after 18 months. For hip width, it decreased again at 24 months. The correlation of chest depth, chest width, area and volume with carcass weight steadily increased over age, while those of other traits decreased toward 24 months. As for the correlation of growth traits with marbling score, those of chest depth and chest girth increased at 24 months of age; those of hip width and pinbone width

Table 5. Rank Correlation among body area, body volume, weight/height ratio and carcass traits of castrated Hanwoo (n=161)

Trait	BF				EMA			
	6	12	18	24	6	12	18	24
BW	0.16*	0.32**	0.39**	0.33**	0.18*	0.36**	0.41**	0.34**
CHD	0.16*	0.33**	0.39**	0.42**	0.13	0.36**	0.37**	0.44**
CHW	0.13	0.28**	0.32**	0.34**	−0.08	0.29**	0.40**	0.23**
CHG	0.20*	0.37**	0.45**	0.43**	0.19*	0.36**	0.44**	0.42**
HW	0.14	0.26**	0.35**	0.41**	0.33**	0.08	0.38**	0.34**
PW	0.19*	0.05	0.17	0.19*	0.42**	−0.26**	0.21**	0.22**
M2	0.21**	0.35**	0.41**	0.32**	0.17*	0.40**	0.42**	0.28**
M3	0.22**	0.34**	0.42**	0.36**	0.19*	0.39**	0.51**	0.34**
Ratio	0.16*	0.29**	0.35**	0.28**	0.19*	0.33**	0.38**	0.35**

Trait	CW				MS			
	6	12	18	24	6	12	18	24
BW	0.30**	0.57**	0.66**	0.64**	0.13	0.25**	0.25**	0.12
CHD	0.29**	0.51**	0.53**	0.59**	0.17*	0.24**	0.26**	0.31**
CHW	0.18*	0.50**	0.56**	0.57**	−0.03	0.28**	0.27**	0.13
CHG	0.33**	0.56**	0.65**	0.68**	0.08	0.31**	0.26**	0.28**
HW	0.31**	0.41**	0.63**	0.62**	0.17*	0.14	0.27**	0.27**
PW	0.35**	0.10	0.40**	0.38**	0.23**	−0.04	0.26**	0.26**
M2	0.37**	0.59**	0.58**	0.58**	0.11	0.28**	0.20*	0.18*
M3	0.38**	0.59**	0.65**	0.66**	0.11	0.26**	0.32**	0.20**
Ratio	0.29**	0.53**	0.60**	0.59**	0.12	0.21**	0.26**	0.10

M2 : body area(cm^2) = body length × ((body height × rump height) / 2);
M3 : body volume(cm^3) = chest depth × body length × ((chest width + thurl width)/2);
LW : live weight; BF : backfat thickness; EMA : eye muscle area; CW : carcass weight; DP : dress percent; MS : marbling score;
** : significant (p<0.01); ns : not significant (p>0.05).

decreased at 12 months but increased again at 18 months. Therefore, we can conclude that the correlation between growth traits and carcass traits is generally the highest at 18 months of age. The rank correlations of chest depth and chest girth with carcass traits were found to be higher than those of other traits. The correlation of hip width and pinbone width with most carcass traits decreased at 12 months of age and increased again at 18 months. The degree of increase of correlation coefficient was recovered to the level at 6 months of age. Thus, we could confirm that the posterior parts corresponded to early ripening traits. Since the degree of rank correlation is not so high, however it is unreasonable to select early the weight and body shape-related traits unconditionally, and the more detailed studies are required through the estimation of distribution components and heredity parameters of each trait.

Ⅳ. ABSTRACT

This study was conducted to figure out how the shape of Hanwoo changes over time, examine the rank correlations between the carcass traits which are the selection traits and parameters of growth curve, and determine the correlation between body shape and carcass. Body weight, body measurements and carcass traits were measured from 161 castrated Hanwoo, and 12 growth traits and 5 carcass traits were investigated in total. The logistic model (Nelder, 1961) used for the estimation of growth curve parameters and growth characteristics at inflection point were calculated by these growth curve parameters. The value of this parameter was greatest for pinbone width, which suggests that it is an early ripening trait, while it was lowest for chest girth, suggesting it to be a late ripening trait. The rank correlations of chest depth, chest width, and hip width with backfat thickness steadily increased from 6 to 24 months, while the rank correlations of other traits decreased after 18 months until 24 months of age. Only phenotypic records were analyzed in this study, but for examine the genetic changes over growth phase in Hanwoo, if another additional genetic analysis like as estimation of genetic parameters should achieve, body measurements may be useful traits in proven bull selection.

Ⅴ. REFERENCES

1. Arango, J. A. and Van Vleck, L. D. 2002. Size of beef cows: early ideas, new developments (review). Genet Mol. Res. 1(1):51.
2. Brown, J. E., Jr. Fitzhugh, H. A. and Cartwright, T. C. 1976. A comparison of nonlinear models for describing weight-age relationships in cattle. J. Anim. Sci. 42:810.
3. Butts, W. T., Jr. Backus, W. R., Lidvall, E. R., Corrick, J. A. and Montgomery, R. F. 1980. Relationships among definable characteristics of feeder calves, subsequent performance and carcass traits. Ⅰ Objective measurements. J. Anim. Sci. 51:1297.
4. Cho, Y. M. 2000. A study on estimation of growth curve parameters and their relationships with economic traits of Hanwoo. Seoul Nat. Univ. in Korea.
5. Cho, Y. M., Yoon, H. B., Park, B. H., Ahn, B. S., Jeon, B. S. and Park, Y. I. 2002. Study on the optimum range of weight-age data for estimation of growth curve parameters of Hanwoo. J. Anim. Sci & Technol. (Kor.) 44(2):165.
6. Cho, K. H., Na, S. H., Choi, J. G., Seo, K. S., Kim, S., Park, B. H., Lee, Y. C., Park, J. D. and Son, S. K. 2006. Estimation of growth curve parameters and analysis of year effect for body weight in Hanwoo. J. Anim. Sci. & Technol. (Kor.) 48(2):151.
7. Fitzhugh, H. A. Jr. 1976. Analysis of growth curves and strategies for altering their shape. J. Anim. Sci. 42(4):1036.
8. Joandet, G. E. and Cartwright, T. C. 1969. Estimation of efficiency of beef production. J. Anim. Sci. 29:862.
9. Johnson, Z. B., Jr. Brown, C. J. and Jr. Brown, A. H. 1990. Evaluation of growth patterns of beef cattle. Arkansas Agric. Exp. Stn. Bull. No. 923, pp. 41.
10. Kim, N. S., Ju, J. C., Song, M. K., Chung, C. S., Choi, Y. I. and Park, C. J. 2002. Growth curve characteristics of bull and steer of Hanwoo (Korean cattle). J. Anim. Sci. & Technol. (Kor.) 44(5):519.
11. Kratochvílová, M., Hyankova, L., Knizetova, H.,

Fiedler, J. and Urban, F. 2002. Growth curve analysis in cattle from early maturity and mature body size viewpoints. Czech J. Anim. Sci. 47(4):125.

12. Lawrence, T. L. J. 1980. Study in the agricultural and food sciences. Growth in Animals. pp 5-7.
13. Lee, C. W., Choi, J. G., Jeon, K. J., Na, K. J., Lee, C., Yang, B. K. and Kim, J. B. 2003a. Estimation of growth curve for evaluation of growth characteristics for Hanwoo cows. J. Anim. Sci. & Technol. (Kor.) 45(4):509.
14. Lee, C. W., Choi, J. G., Jeon, G. J., Na, K. J., Lee, C., Hwang, J. M., Kim, B. W. and Kim, J. B. 2003b. Estimation of parameters for individual growth curves of cows in Bostaurus Coreanae. J. Anim. Sci. & Technol. (Kor.) 45(5):711.
15. Lee, C. W., Choi, J. G., Jeon, K. J., Na, K. J., Lee, C., Hwang, J. M. and Kim, J. B. 2003c. Factors affecting grwoth curve parameters of Hanwoo cows. J. Anim. Sci. & Technol. (Kor.) 45(5):711.
16. Long, C. R., Cartwright, T. C. and Jr. Fitzhugh, H. A. 1975. Systems analysis of source of genetic and environmental variation in efficiency of beef production: Cow size and herd management. J. Anim. Sci. 40:409.
17. Lopez de Torre, G., Candotti, J. J., Reverter, A., Bellido, M. M., Vasco, P., Garcia, L. J. and Brinks, J. S. 1992. Effects of growth curve parameters on cow efficiency. J. Anim. Sci. 70:2668.
18. Nelder, J. A. 1961. The fitting of a generalization of the logistic curve. Biometrics. 19:89.
19. SAS. 1990. SAS/STAT User's guide vol. 2. SAS institute Inc., Cary, NC., USA.
20. Tawah, L. C. and Franke, D. E. 1985. Growth parameters and reproduction in purebred and crossbred beef cattle. J. Anim. Sci. 61(Suppl. 1):8 (Sbstr).

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