



Estimation of Genetic Parameters for Real-time Ultrasound Measurements for Hanwoo Cows at Different Ages and Pregnancy Status

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ABSTRACT: The purpose of this study was to estimate genetic parameters of ultrasound measurements for *longissimus dorsi* muscle area (LMA), backfat thickness (BFT), and marbling score (MS) in Hanwoo cows (N = 3,062) at the ages between 18 and 42 months. Data were collected from 100 Hanwoo breeding farms in Gyeongbuk province, Korea, in 2007 and 2008. The cows were classified into four different age groups, i.e. 18 to 22 months (the first pregnancy period), 23 to 27 (the first parturition), 28 to 32 (the second pregnancy), and 33 to 42 (the second parturition), respectively. For each age group, a multi-trait animal model was used to estimate variance components and heritabilities of the three traits. The averages of LMA, BFT, and MS measurements across the cows of all age groups were 50.1 cm², 4.62 mm, and 3.04, respectively and heritability estimates were 0.09, 0.10, and 0.08 for the respective traits. However, when the data were analyzed in different age groups, heritability estimates of LMA and BFT were 0.24 and 0.47, respectively, for the cows of 18 to 22 months of age, and 0.21 for MS in the 28 to 32 months old cows. When the cows of all age groups were used, the estimates of genetic (phenotypic) correlations were 0.43 (0.35), -0.06 (0.34) and 0.21 (0.32) between LMA and BFT, LMA and MS, and BFT and MS, respectively. However, in the cow age group between 28 and 32 (18 and 22) months, the estimates of genetic (phenotypic) correlations were 0.05 (0.29), -0.15 (0.24) and 0.38 (0.24), for the respective pairs of traits. These results suggest that genetic, environmental, and phenotypic variations differ depending on cow age, such that care must be taken when ultrasound measurements are applied to selection of cows for meat quality. (**Key Words:** Real-time Ultrasound, Heritability, Cows, Hanwoo)

INTRODUCTION

Real-time ultrasound measurement is a technology for early evaluation of meat quality without carcass processing (Ludwig, 1950; Howry and Bliss, 1952). Temple et al. (1956) measured subcutaneous fat using A-mode (amplitude modulation) at the first stage of ultrasound measurement, followed by the use of B-mode (bright modulation) in 1968. However, the two types of

measurements did not enable well definition of lipid and muscle in the meat tissues.

A more practical application of real time ultrasound was reported by Waldner et al. (1992), in which *longissimus dorsi* muscle area (LMA) and backfat thickness (BFT) were measured in Brangus bulls at 4 to 24 months of age. There were other reports in which ultrasound measurements were used to predict carcass quality traits before slaughtering (Perkins et al., 1992; Herring et al., 1998). Since 1990, the application of ultrasound measurements were extended to estimate genetic parameters for young bulls and heifers, so as to reduce time and cost for progeny testing (Shepard et al., 1996; Moser et al., 1998; Reverter et al., 2000; Crews et al., 2002; Stelzleni et al., 2002; Crews et al., 2004; Pinheiro et al., 2011).

There were several studies about repetitive ultrasound measurements for genetic parameter estimation (Hassen et al., 1999; Hassen et al., 2004; Pinheiro et al., 2011). Hassen et al. (1999) reported that standard errors of the estimates of

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intramuscular fat decreased as the number of repetitive measurement increased, e.g. from the 1st to the 6th times. Houghton and Turlington (1992) pointed out that adjustments for ultrasound equipment and protocol as well as breed, age and body weight of animals had to be made to obtain accurate estimates. The most common cattle breeds for which ultrasound has been used are Angus, Brangus, Hereford, and Simmental, of which young bulls and heifers were used for genetic parameter estimation of LMA, BFT and marbling score (MS). Hassen et al. (2004) reported that the most appropriate age for ultrasound measurements was 12 months in Angus, and when animals were used that were younger than 320 days or older than 410 days, the estimates had less accuracy (BIF, 1996).

Heritability estimates of LMA, BFT, and intramuscular fat (%) have been reported in the range of 0.11 to 0.61, 0.11 to 0.69, and 0.16 to 0.52, respectively (Shepard et al., 1996; Moser et al., 1998; Hassen et al., 1999; Reverter et al., 2000; Crews et al., 2002; Stelzleni et al., 2002; Crews et al., 2004; Hassen et al., 2004; Pinheiro et al., 2011).

Roh et al. (2010) reported that heritabilities for ultrasound measured LMA, BFT and MS in Hanwoo cattle were estimated to be 0.57, 0.41, and 0.14 at 12 months of age, and 0.57, 0.60, and 0.22 at 24 months of age, respectively, in performance testing bulls and progeny testing steers. In a Hanwoo cow population in which the cows were older than 18 months of age, heritability estimates using ultrasound measurements were 0.14 to 0.39, 0.19 to 0.48, and 0.13 to 0.38 for LMA, BFT, and MS, respectively, in Koo (2007), Yoon (2010) and Choy et al. (2011). However, in their reports, the genetic parameters for the ultrasound measures were not estimated in homogeneous age groups, i.e. the age of the cows in the samples varied between 18 and 60 months.

The purpose of this study, therefore, was to estimate genetic parameters of ultrasound measurements at various age groups in an effort to better understand genetic variability at different ages in a Hanwoo cow population.

MATERIALS AND METHODS

Animals and phenotype data

The Hanwoo cows that were used in this study were born between 2000 and 2007, and were between the ages of 12 and 42 months. The ultrasound measurement data were collected from 100 Hanwoo commercial farms in Gyeongbuk province in 2007 and 2008, mainly by one trained technician. The cows were classified into four different age groups, i.e. the first pregnancy period (683 cows between 18 and 22 months), the first parturition period (794 between 23 and 27), the second pregnancy period (861 between 28 and 32), and the second parturition period (724 between 33 and 42). The ultrasound traits were

longissimus dorsi muscle area (cm²; LMA), backfat thickness (mm; BFT), and marbling score (MS), which were measured between the 13th rib and 1st lumbar vertebrae with a Medicine (Ltd.) Pico v103 instrument (cm, 3.5 MHz linear array probe). The MS was scored from the ultrasound image by eye, as one through nine according to the Korean Beef Marbling Standard (1 = trace, 9 = very abundant). Body condition scores were also measured as levels 1 through 5 at the same time of measuring the ultrasound traits.

Statistical model

A multi-trait animal model was used for genetic parameter estimation of the ultrasound measures;

$$Y = \mu + Bys + Tys + LF + BCS + age + a + e$$

Where, Y is a dependent variable, the measurement of each trait, μ is overall mean, *Bys* is a fixed effect of birth year and season (28 levels), *Tys* is a fixed effect of year and season (eight levels), *LF* is a fixed effect of farm (100 levels), *BCS* is a fixed effect of body condition score (five levels), *age* is a covariate of months of age, *a* is a random effect of additive genetic effect of each individual, and *e* is a random effect of random error. Estimation of variance components were based on a multi-trait animal model using REML method with ASREML program (Gilmour et al., 1999), across all ages or for each age group of cows.

RESULTS AND DISCUSSION

Statistics for real-time ultrasound and body condition score measurements in Hanwoo cows are shown in Table 1 and Figure 1. There were increasing trends in the measurement of the ultrasound traits during the first pregnancy period (18 to 22 months of age), decreasing in the parturition period (23 to 27 months of age), increasing in the second pregnancy (28 to 32 months), and decreasing in the second parturition periods (33 to 37 months of age). Because lactation requires a great amount of energy, it is commonly known that BFT accretion decreases at the parturition times, in which primiparous cows under the strain of both body growth and the first lactation may be exposed to reduction of muscling. The averages of ultrasound measures for the cows across all age groups were 50.1 cm², 4.62 mm, and 3.04 for LMA, BFT, and MS, respectively. The averages in the first and the second pregnancy periods were 49.7 cm² and 50.2 cm², 4.51 mm and 4.69 mm, and 2.48 and 3.42, for the respective traits, which was in general agreement with the fact that LMA or fat deposition increase with age. Increments of muscling and fat deposition with age were also observed in Japanese Black as well as European cattle breeds (Gotoh et al., 2009).

Table 1. Statistics for real-time ultrasound and body condition score measurements in Hanwoo cows of different age groups and pregnancy status

Trait	Age (mean of month)	N	Mean	Std	Min	Max
LMA (cm ²)	18-22 (20.6)	683	49.7	6.46	33	72
	23-27 (25.2)	794	49.1	7.12	30	85
	28-32 (29.8)	861	50.2	7.65	31	76
	33-42 (37.6)	724	51.6	7.70	29	82
	Overall (28.4)	3,062	50.1	7.33	29	85
BFT (mm)	18-22 (20.6)	683	4.51	1.74	1	12
	23-27 (25.2)	794	4.31	2.00	1	13
	28-32 (29.8)	861	4.69	2.31	1	15
	33-42 (37.6)	724	4.99	2.60	1	16
	Overall (28.4)	3,062	4.62	2.20	1	16
MS	18-22 (20.6)	683	2.48	1.83	1	14
	23-27 (25.2)	794	2.95	2.01	1	18
	28-32 (29.8)	861	3.42	2.48	1	18
	33-42 (37.6)	724	3.21	2.55	1	22
	Overall (28.4)	3,062	3.04	2.27	1	22

LMA = *Longissimus dorsi* muscle area, BFT = Backfat thickness, MS = Marbling score (1 to 9).

There are several reports about ultrasound measurements in beef cattle, in which breed, age and sex influenced muscle and fat deposition (Zhou et al., 2001; Yokoo et al., 2006; Gotoh et al., 2009). Crews et al. (2004) reported that ultrasound measurements for LMA, BFT and intramuscular fat (%) were 66.1 cm², 3.94 mm, and 3.40, respectively, in Simmental heifers at 12 months of age. Robert et al. (2007) reported 58.8 cm², 3.96 mm, and 3.52 for the respective traits in 1/2 red Angus, 1/4 Charolais, and 1/4 Tarentaise heifers of 12 months of age. Pinheiro et al. (2011) reported 47.5 cm² and 1.34 mm for LMA and BFT in Nelore bulls and heifers at 10 to 26 months of age, 45.3 cm² and 1.03 mm at 11 to 17 months, and 49.0 cm² and 1.94 mm at 18 to 24 months, respectively. Choy et al. (2011) reported 50.8 cm², 2.74 mm, and 1.73 for LMA, BFT and MS in a

sample of Hanwoo cows at 24 months or younger age. Compared with the results in this study, the values of Choy et al. (2011) were slightly greater for LMA and smaller for BFT and MS, and ranged within one standard deviation of the respective traits (Table 1).

Heritabilities

Heritability (h^2) estimates for LMA, BFT, and MS ultrasound measures in Hanwoo cows are shown in Table 2. The h^2 estimates across all ages of the cows were 0.09, 0.10, and 0.08 for the respective traits. In the cow group of 18 to 22 months of age, the h^2 estimates for LMA and BFT were 0.24 and 0.47, which were the greatest among the four groups of cow age for the respective traits. Also, for the age group, the estimates of genetic variance were 6.79 and 0.83

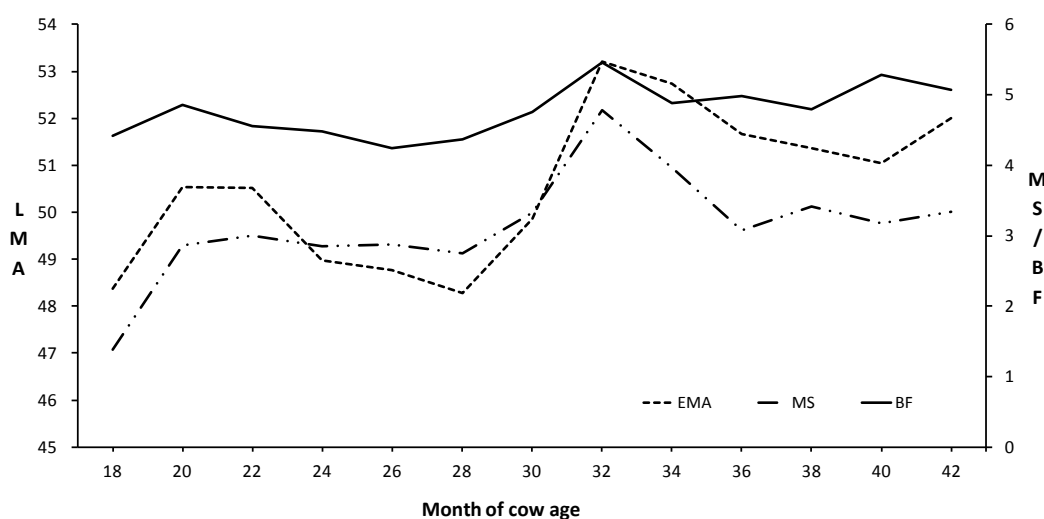


Figure 1. Average measurements of real-time ultrasound traits on month of age in Hanwoo cows. LMA = *Longissimus dorsi* muscle area (cm²), BF = Backfat thickness (mm), MS = Marbling score.

Table 2. Genetic variance (σ_a^2), residual variance (σ_e^2), and heritability (h^2) of real-time ultrasound traits in Hanwoo cows in different age groups

Trait	Age (mean of month)	N	σ_a^2	σ_e^2	h^2
LMA (cm ²)	18-22 (20.6)	683	6.79±4.72	21.8±4.00	0.24±0.16
	23-27 (25.2)	794	4.74±3.24	30.6±3.14	0.13±0.09
	28-32 (29.8)	861	4.44±2.75	24.5±2.56	0.15±0.09
	33-42 (37.6)	724	3.07±3.22	29.8±3.19	0.09±0.10
	Overall (28.4)	3,062	3.02±1.16	30.3±1.21	0.09±0.03
BFT (mm)	18-22 (20.6)	683	0.83±0.30	0.92±0.24	0.47±0.15
	23-27 (25.2)	794	0.11±0.15	1.94±0.17	0.05±0.07
	28-32 (29.8)	861	0.12±0.14	2.11±0.16	0.05±0.06
	33-42 (37.6)	724	0.25±0.29	2.41±0.28	0.09±0.11
	Overall (28.4)	3,062	0.23±0.09	2.05±0.09	0.10±0.04
MS (1 to 9)	18-22 (20.6)	683	0.34±0.27	1.64±0.24	0.17±0.13
	23-27 (25.2)	794	0.08±0.18	2.73±0.22	0.03±0.07
	28-32 (29.8)	861	0.73±0.39	2.69±0.34	0.21±0.11
	33-42 (37.6)	724	0.51±0.37	3.27±0.37	0.13±0.10
	Overall (28.4)	3,062	0.26±0.11	2.91±0.11	0.08±0.03

LMA = *Longissimus dorsi* muscle area, BFT = Backfat thickness, MS = Marbling score (1 = trace, 9 = abundant).

σ_a^2 = Genetic variance, σ_e^2 = Residual variance, h^2 = Heritability.

(the greatest among the age groups), and those of residual variance were 21.8 and 0.93 (the smallest) for LMA and BFT, respectively (Table 2). The greatest heritability for MS ($h^2 = 0.21$) was obtained for the group of cows at 28 to 32 months old.

Shepard et al. (1996) reported that h^2 estimates for LMA and BFT ultrasound measures were 0.12 and 0.50 in Angus bulls and heifers at 8 to 20 months of age. Stelzleni et al. (2002) reported 0.31, 0.26, and 0.16 in Brangus bulls ($n = 1,073$) and heifers ($n = 226$) at 10.6 to 13.6 months of age for LMA, BFT, and intramuscular fat (%), respectively. These h^2 estimates were close to the estimates in the cow group of 18 to 22 months of age in this study (Table 2).

Moser et al. (1998) reported that, when ultrasound measurements were combined with progeny testing results, h^2 estimates were 0.29 and 0.11 for ultrasound LMA and BFT in Brangus bulls and heifers of 10 to 14 months of age. Reverter et al. (2000) reported h^2 estimates of 0.46, 0.54, and 0.47 in Angus heifers and 0.34, 0.27, and 0.12 in Hereford heifers for LMA, BFT and intramuscular fat (%) ultrasound measures, respectively. Crew et al. (2004) reported h^2 estimates of 0.51, 0.69, and 0.52 for the respective ultrasound traits in Simmental bulls and heifers of 12 months of age, when the data were combined with carcass traits by progeny testing. These results suggest that there is a tendency toward upward estimation of heritability, when data of ultrasound measurements are combined with carcass traits by progeny testing.

In Hanwoo, Koo (2007) reported that h^2 estimates were 0.17, 0.19, and 0.13 for ultrasound LMA, BFT and MS,

respectively, in a sample of cows ($N = 12,064$) that were measured at 20 or older months of age from many Hanwoo breeding farms between 2001 and 2006. Yoon (2010) reported 0.15, 0.39, and 0.38 in Hanwoo cows ($N = 21,640$), while Choy et al. (2011) reported 0.39, 0.48, and 0.13 for the respective ultrasound traits in Hanwoo cows ($N = 6,629$) with 15 or older months of age in Hanwoo breeding farms of Gyeonggi province. Our results showed that, in general, the h^2 estimates across all age groups of cow were lower than the reports of Koo (2007), Yoon (2010) and Choy et al. (2011). However, when the group of cows between 18 and 22 months of age, the h^2 estimates of LMA and BFT were greater than those in Koo (2007) and Yoon (2010), and for the cows at 28 to 32 months of age, the h^2 estimate of MS was greater than those in Koo (2007) and Choy et al. (2011) (Table 2).

In beef cattle of western breeds such as Angus or Simmental, measurement age of ultrasound traits was consistent, i.e. 12 months. However, ultrasound traits were measured in various ages in Hanwoo cows (Koo, 2007; Choy et al., 2011). Hassan et al. (2004) classified the ultrasound measures in six different age groups (8.1, 9.2, 10.6, 11.7, 12.3, and 13.4 months) in Angus bulls and heifers, and reported that heritability estimates ranged between 0.30 and 0.48 for LMA, for which h^2 estimate was the greatest in 11.7 to 13.4 months of age. Pinheiro et al. (2011) also classified ages into several groups for LMA and BFT in Nelore bulls and heifers, and they reported that the h^2 estimates were 0.46 and 0.26 for 11 to 17 months and 0.33 and 0.24 for 18 to 24 months of age, for the respective

traits. Our results also showed different h^2 estimates in various age groups (Table 2), suggesting that care must be taken when ultrasound measurements are applied to selection of cows for meat quality.

Genetic and phenotypic correlations

Genetic (r_g) and phenotypic (r_p) correlations between the three ultrasound traits are described in Table 3. Across all the age groups of cows, the r_g estimates were 0.43, -0.06, and 0.21, and the r_p estimates were 0.35, 0.34, and 0.32 between LMA and BFT, LMA and MS, and BFT and MS, respectively. Since LMA and BFT increase with age and both BFT and MS are measures of adiposity, it is not surprising to get positive genetic and phenotypic relationship between the traits. When only the data from the Hanwoo cows at 18 to 22 months of age were used, the r_g estimates were 0.40, 0.02, and 0.22, and the r_p estimates were 0.29, 0.24, and 0.24 for the respective pairs of traits. However, in an older age group (28 to 32 months), the r_g and r_p estimates were 0.05, -0.15, and 0.38, and 0.34, 0.35, and 0.35, respectively. The different estimates of r_g and r_p between various cow age groups may be partly due to different estimates of genetic and environment components. In conclusion, our results suggest that, as cow age and pregnancy status may be important factors in influencing variability of ultrasound measures between cows, care should be taken in collection data of ultrasound measures and estimation and evaluation of genetic parameters in Hanwoo cows with different ages.

Table 3. Genetic (above the diagonal) and phenotypic (below the diagonal) correlations for real-time ultrasound measures in Hanwoo cows of different age groups

Age (months)	Trait	LMA	BF	MS
18-22	LMA	-	0.40±0.31	0.02±0.52
	BF	0.29±0.04	-	0.22±0.37
	MS	0.24±0.04	0.24±0.04	-
23-27	LMA	-	-0.11±0.73	-0.11±0.96
	BF	0.36±0.03	-	0.38±0.52
	MS	0.31±0.04	0.29±0.04	-
28-32	LMA	-	0.05±0.63	-0.15±0.43
	BF	0.34±0.03	-	0.38±0.52
	MS	0.35±0.04	0.35±0.03	-
33-42	LMA	-	0.56±0.69	0.38±0.58
	BF	0.36±0.04	-	0.09±0.64
	MS	0.32±0.04	0.27±0.04	-
Overall	LMA	-	0.43±0.22	-0.06±0.28
	BF	0.35±0.02	-	0.21±0.26
	MS	0.34±0.02	0.32±0.02	-

LMA = *Longissimus dorsi* muscle area, BF = Backfat thickness, MS = Marbling score.

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