Evaluation and optimal utilisation of the international linear type classification schemes

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1. SUMMARY

The main objectives of this study were: 1) to evaluate the phenotypic associations between linear type traits and survival in New Zealand and identify potential new traits for inclusion in the type classification scheme in Ireland, and 2) to quantify the potential of linear type traits scored in Ireland as early predictors of genetic merit for fertility and survival in Ireland.

Linear type traits, which describe biological extremes, have been scored predominantly in pedigree registered dairy animals in most countries, including Ireland, for several decades. To date their usefulness as early predictors of functionality and survival has not been fully evaluated under Irish conditions. In New Zealand, these type traits, referred to as "traits other than production" are also scored but scored in predominantly progeny test herds unlike in Ireland where most of the data on linear type traits originate from pedigree status animals.

Analysis of national New Zealand data revealed that management traits such as speed of milk and temperament, but in particular a trait called “farmer opinion” which evaluated, on a scale of 1 to 9 ,what a farmer thought of an animal, were strongly correlated with survival, moreso that traits describing the physical conformation of the animal. Analysis of this “farmer satisfaction” trait in Ireland revealed that it was heritable and thus breeding values for farmer satisfaction could be generated as part of routine genetic evaluations. Further research on this trait, mainly relating to the method of recording and its association with other traits needs to be further investigated.

Moderate genetic correlations existed between some of the type traits and calving interval and survival in Ireland. Type traits currently included as predictors of calving interval and survival in Ireland are body condition score, angularity, foot angle and udder depth. This will facilitate more accurate estimation of breeding values for sires with little information on calving interval and survival.

2. INTRODUCTION

Selection within the Holstein-Friesian breed has until recently been predominantly for milk production (Miglior *et al.*, 2005) with little or no direct cognisance for functional traits. However, most functional traits (e.g., fertility) are lowly heritable (Berry et al., 2003) and/or take a long time to measure (e.g., survival) as well as sometimes being difficult to measure in progeny testing schemes. Low heritability implies that in a progeny testing scheme, large progeny group sizes are a necessity to obtain accurate estimates of genetic merit of a sire; this implies a greater cost of progeny testing. Furthermore the long time interval to measurement of these traits means a potentially greater generation interval and thus lower annual genetic gain. One method to circumvent such drawbacks of functional traits is to identify traits, that are already routinely measured early in life and are correlated with some functional traits, and select for these traits to obtain correlated responses in the functional traits of interest.

Linear type conformation traits describe biological extremes for a range of visual characteristics of an animal. Previous international research suggests that some of these traits are moderately heritable (Cue et al., 1996; Brotherstone et al., 1990; Short and Lawlor, 1992) and are genetically correlated with functional traits (Cue et al., 1996). EXAMPLES. However, to date there has been no comprehensive study on the phenotypic and genetic parameters of linear type traits in Irish Holstein-Friesian cows and their phenotypic and genetic associations with functional traits in Ireland.

The main objectives of this study were: 1) to evaluate the phenotypic associations between linear type traits and survival in New Zealand and identify potential new traits for inclusion in the type classification scheme in Ireland, and 2) to quantify the potential of linear type traits scored in Ireland as early predictors of genetic merit for fertility and survival in Ireland.

3. MATERIALS AND METHODS

Two separate datasets and distinct analyses were performed in the present study 1) phenotypic associations between linear type traits and survival in New Zealand dairy herds and, 2) the change in linear type traits of Irish Holstein-Friesians over the past decade as well as phenotypic and genetic parameters of linear type traits in Ireland

3.1 New Zealand

Data were extracted from the New Zealand national database on 15th March 2004 on all primiparous cows that were type classified throughout the years 1987 and 2003. In New Zealand, 17 type traits are assessed on a scale of 1 to 9; 4 traits are scored by the dairy farmer (adaptability to the milking routine, speed of milking, temperament and overall farmer opinion) and the remaining 13 by industry trained classifiers primarily from the breed societies (stature, capacity, rump angle, rump width, legs, live-weight, udder support, fore udder attachment, rear udder height, front teat placement, rear teat placement and two composite traits udder overall and dairy conformation). All type traits are described in more detail by Cue et al. (1996). Only the first classification record per cow was retained. The type traits (following re-scaling using the Snell transformation) were pre-adjusted for age at first calving, nested within breed, and stage of lactation at classification. Residuals were standardised within contemporary group of herd-year-season and were subsequently transformed to a qualitative variable with 20 classes: intervals of 0.2 SD between ±1SD, subsequent intervals of 0.5 SD to ±3SD, and two final classes of >|3SD|.

Spring calving cows were considered to be right censored if an official record was available on the cow after the 1st June 2003 and the cow subsequently did not die or was not culled; spring calving cows were cows that calved in the last six months of the year. Similar censoring criteria were applied for autumn calving cows except that the cow had to have an official record after the 1st January 2003; autumn calving cows were cows that calved in the first six months of the year. Animals culled due to low production or moved into unrecorded herds were treated as censored at the time of culling or sale.

Breed was classified as Holstein-Friesian, Jersey or Holstein-Friesian X Jersey crossbreds. Herd-year contemporary groups were created for each cow at each calving. Contemporary groups with less than four non-censored records were removed and the record was coded as censored at the time when the cow entered that contemporary group. Lactation yield deviations for milk, fat and protein (Johnson, 1996) were extracted from the national database for each cow-lactation and were subsequently standardised within contemporary group and converted to a qualitative variable with 20 classes as performed for the type traits. Production values for milk volume, protein yield, fat yield, and live-weight (Harris et al., 1996) were extracted from the animal evaluation database for each individual cow and was divided into deciles.

A qualitative variable (i.e., calving period) with six classes representing intervals of 15 days from the start of the calving season was generated for each herd-year. Each cow received a record for this variable based on her most recent calving. Proportion of genes of each breed and heterosis between crosses was converted to a quantitative variable with 11 levels: 0% and 10 subsequent levels each representing 10 percentage units increments.

Cows that had no information on a type trait were assigned into a separate class for each trait. In total 259,280 cows were included in the analysis. All analyses were undertaken using a proportional hazards Cox model in "The Survival Kit V3.0" (Ducrocq and Solkner, 1998). The hazard function was defined as the baseline hazard function, stratified by breed, times the exponent of the solutions for contemporary group (class variable; time dependent), age at first calving (time independent), heterosis (class variable; time independent), proportion of genes of each breed (class variable; time independent), calving period (class variable; time independent), type trait (class variable; time independent), cow pedigree status (class variable, time independent), production value (class variable; time independent), and lactation deviation (class variable; time dependent). The production values and lactation deviation explanatory variables were only included in the analysis of functional longevity; longevity prior to adjusting for production values and lactation deviation is termed true longevity herein. The significance of effects in the model was tested using the likelihood ratio test between nested models.

3.2 Ireland

3.2.1. Change in type across years

In order to quantify any change in conformation of animals over time in Ireland, 57,592 records, with information on cow identification number, herd, and calving month for cows with data on 17 different type traits, as well as the year of inspection, age at inspection, and lactation stage at inspection were extracted from the Irish Cattle Breeding Federation database. Only the first type trait record in time, scored on first lactation animals calving between 1995 and 2005, from herd-years that had at least three type trait records were retained. The final data set consisted 47,953 cows from 1,960 herds. A second data set was created containing only the 57 herds that had type trait information for each of the 11 years of the study. A total of 8,842 cows were included in this analysis. The data were analysed using a linear multiple regression model in ASREML (Gilmour et al., 2006) which included fixed effects of herd, year, calving month, age at inspection and stage of lactation at inspection. Annual least squares means were extracted from the analysis and a linear regression line fitted through the resultant least squares means.

3.2.2. Estimation of phenotypic and genetic parameters

A total of 104,039 records were extracted from the Irish Cattle Breeding Federation (ICBF) database on up to 22 different linear type traits and four composite traits throughout the years 1990 to 2004. Definition of the linear type traits and composite traits recorded in Ireland are summarised in Table 2. Following the removal of herds with less than four records, herds without a valid national identification number and cows scored prior to 25 months of age or after 44 months of age, 70,813 records remained. Only the first record scored per cow was retained; 63,011 cow records remained.

Data were also extracted from the ICBF database on 1,878,078 cows with records on standardized 305-day milk yield and calving dates for either parity one (1,178,401 records), parity two (945,170 records), parity three (766,121 records), parity four (613,959 records), or parity five (480,615 records). Standardised 305-day milk yield was calculated using the standard lactation curve methodology described by Olori et al. (1999). Lactations with a 305-day milk yield less than 1,000 kgs or greater than 15,000 kgs were removed from the analysis as were parities with a subsequent calving interval outside the range of 300-800 days were removed. Herd records without a valid national identification number were also removed from the analysis and a random selection of data based on the final digit of the national herd identification code were retained; 30% of the data were retained. Following these edits, 589,830 cows remained.

Data on type traits and lactation performance were merged. Animals with no sire identified were removed (180,013 cows). Milk production and calving interval records were set to missing for cows that had information on linear type traits. Herd-year records with less than 15 animal records were removed; 377,107 cows remained. An iterative algorithm removed cows in herds with less than fifty records in the dataset and from sires with less than ten daughters. Only daughters of Holstein-Friesian sires were retained; 49,293 cows were removed. For animals with records on type traits, contemporary groups of herd-year-season (i.e., Spring, Summer, Autumn, Winter) of type classification were created and contemporary groups with less than four records were removed. Following this edit 49,093 cows with type trait records remained in the dataset.

An iterative algorithm similar to that described by Crump et al. (1997) and Schmitz et al. (1991) was to generate contemporary groups of calving within parity having at least five records per group.

Age at calving was recoded into a classification variable within parity based on the frequency distribution of the records within parity. For parity one, age at calving classes were defined as <700 days, 701-750 days, 751-800 days, 801-950 days, and 950-1150 days of age. Age classes derived for parity two and three were <900 days, 901-1050 days, 1051-1150 days, 1151-130 days, 1301-1450 days and <1250 days, 1251-1450 days, 1451-1550 days, 1551-1850 days, respectively.

Two definitions of survivability were adopted in the present study. Survival was firstly defined as whether an animal survived (i.e., survival= 1) or not (i.e., survival=0) to parity *i* given it was alive at parity *i-1*; this variable is herein referred to as survival. Survivability was also defined in accordance with procedures outlined by Brotherstone et al. (1997) and will herein be referred to as lifespan. The last official date (i.e., milk test-day, calving date) per herd was extracted from the data. A record was also available on the last known parity of an animal. If an animal's last know parity was greater that *i*, then the animal was assumed to have survived her i^{th} lactation. Alternatively, if the last known official date of a cow was greater than 140 days from the last official herd date then the animal was assumed to have not survived that lactation (i.e., survival=0). Cows not conforming to either of the above criteria had their survival variable set to missing. Additionally cows with information on type traits had their survival variables coded as missing.

Lifespan was included in the analysis in order to avoid to loss any information associated with cows coded as missing for survival. A cow was given a lifespan score of *i*-1 if the animal was known to have not survived to parity *i*. Where the fate of an animal was unknown (i.e., she was not coded as being culled and her last known calving date was within 800 days from the date of data extraction) then her lifespan score was calculated as:

$$LS = n + \sum_{i=n+1}^{25} \prod_{i=n+1}^{25} s_i$$

where *n* is the number of lactations the animal is known to have survived and *s* is the survival vector with each element denoting the probability of an animal surviving from age *i-1* to age *i*. The survival probability vector was derived from the data for the first five lactations and was assumed to decrease at a constant rate of four percentage units thereafter. No lifespan score was allocated to cows with information on type traits.

The number of records included in the analysis are summarised in Table 2 and 3 for the type traits, milk yield, calving interval, survival and lifespan. The fewer number of records for body condition score, udder texture, locomotion, rear teat placement, bone quality, temperament, and ease of milking compared to other type traits is because these traits were introduced more recently to the type classification scheme or were not scored on all animals.

Because of excessive computational demands for a full multi-trait analysis across all traits it was decided to undertake a series of multi-trait analyses across four traits including always milk yield, survival and calving interval within parity. Each analysis contained a different type trait. The procedure was carried out within all three parities separately. Lifespan replaced survival in a four trait analysis with milk, calving interval for first parity only and each individual type trait. All analyses were performed in ASREML (Gilmour et al., 2005) using a sire model with three generations of relationships among sires accounted for through the relationship matrix. The pedigree file describing the relationships among sires contained 13,021 animals.

Within the linear model used, milk yield, calving interval and survival were adjusted for the fixed effects of contemporary group and age at calving; both variables were included as classification variables. Type traits were adjusted for a herd-year-season of classification visit, month of calving, stage of lactation at classification (recoded in thirty day increments from calving) and a quadratic regression on age at classification defined in months. All traits were adjusted for breed of the cow and breed of the sire.

No environmental covariance existed between the type traits and milk yield, survival/lifespan and calving interval. However, the environmental covariances in a sire model contain ¾ of the additive genetic covariances and therefore the environmental covariances with each type trait were restricted to be three times the sire covariances between the corresponding traits. Correlations between type and the other traits were therefore estimated though the genetic linkages among sires across the different herd types, thereby minimising the possibility of introducing bias accruing from pedigree farmers retaining animals because of their superior physical characteristics.

Functional survival/longevity may be approximated by adjusting survival/longevity for differences in milk yield (Ducrocq et al., 1988). Meuwissen et al. (2002) reported that when undertaking a multi-trait analysis that included milk yield as a component trait, then genetic adjustment of survival for milk yield was similar to a phenotypic pre-adjustment of survival for yield. This variable will be herein referred to as functional survival and similarly functional lifespan when lifespan is adjusted for genetic differences in milk yield. Correlations between type and functional survival and lifespan were calculated using methodology described by Kennedy et al. (1993).
Selection index methodology (Hazel, 1943) was used to identify the marginal increase in accuracy of selection for calving interval accruing from the stepwise inclusion of additional traits in a subindex.

3.2.3 Farmer satisfaction

In 2005 and 2006, farmers participating in the national dairy sire progeny testing scheme were asked to score all their first lactation animals for overall satisfaction using a scale of 1 to 5: 1=strongly disliked, 2=disliked, 3=average, 4=liked, and 5=liked very much. Following the removal of herds that reported no variation in animal satisfaction, scores on 2,396 primiparous animals across 316 herds remained. An animal model including the fixed effects of herd-year, age at first calving and days in milk at scoring was fitted in ASREML (Gilmour *et al.,* 2004); the dependent variable was the exponent of farmer satisfaction score. A series of bi-variate analyses were also undertaken to estimate genetic and residual covariances between farmer satisfaction and total lactation yield for milk, fat and protein as well as fat and protein composition and somatic cell score (i.e., $\log_e$ somatic cell count). Pedigree information three generations deep was collated; the pedigree file consisted 5,982 non-founder animals. Spearman rank correlations between farmer satisfaction and the individual animal's economic breeding index (i.e., the total merit index in Ireland) and type traits were also undertaken; a total of 1,119 animals had information on farmer satisfaction, EBI and type traits.

4. RESULTS AND DISCUSSION

4.1 Phenotypic associations in New Zealand

All type traits had a significant ($P<0.001$) effect on both true and functional longevity as quantified by the change in log likelihood (Figure 1). Farmer opinion of the cow in first lactation (scored on average between 90-100 days of lactation) relative to her contemporaries was the most influential of all the type traits on true and functional longevity. The importance of farmer opinion, relative to other type traits, diminished following adjustment of longevity for the relative milk production of the cow. Previous analysis in New Zealand revealed heritability estimates of 0.12 to 0.36 for farmer opinion and moderate to strong genetic correlations between farmer opinion and survival (Cue et al., 1996). The influence of the other farmer scored traits on longevity was similar to those of the classifier scored traits. The two composite traits (udder overall and dairy conformation) also had a large influence on true and functional longevity.

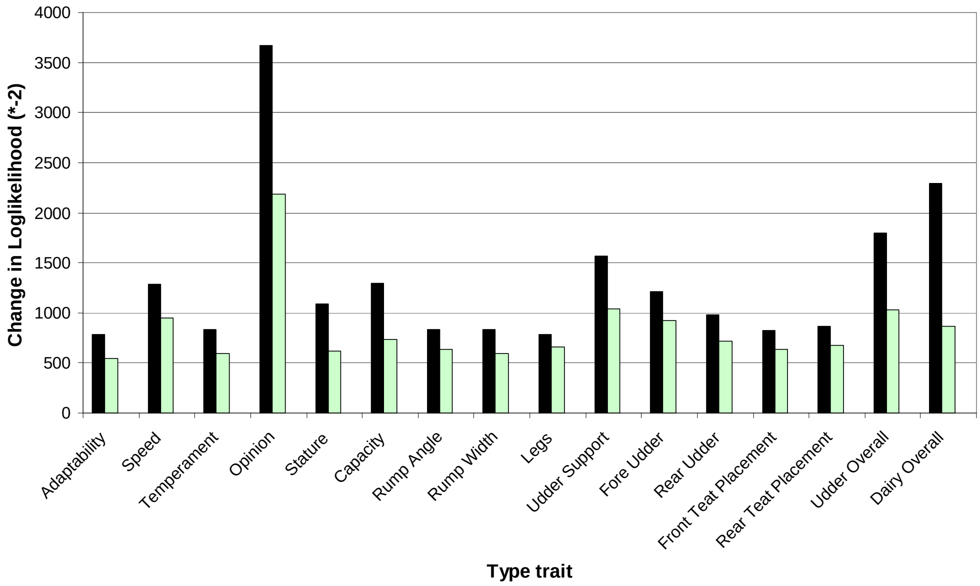

Figure 1. *Contribution of each type trait to the change in log-likelihood for true (■) and functional (□) longevity.*

Of the individual type traits describing the physical characteristics of the cow, the udder related traits had the largest effect on functional longevity agreeing with previous international studies (Short and Lawlor, 1992; Schneider et al., 2003). Of the individual udder traits investigated in the present study, udder support had the largest influence on true and functional longevity. Udder support is sometimes referred to as median suspensory (Schneider et al., 2003), suspensory ligament (Vollema et al., 2000) or udder cleft (Larroque and Ducrocq, 2001) although in New Zealand udder support, also includes an element of udder depth relative to the hocks. Udder support has also been shown in other international studies (Vollema et al., 2000; Larroque and Ducrocq, 2001; Schneider et al., 2003) to be one of the most important udder traits in relation to true and functional longevity along with udder texture. These results suggest that cows with healthy udders are better able to withstand the stress of milk production and remain healthy and fertile thereby persisting in the herd longer. The low relative importance of legs as an indicator of longevity agrees with Larroque and Ducrocq (2001).

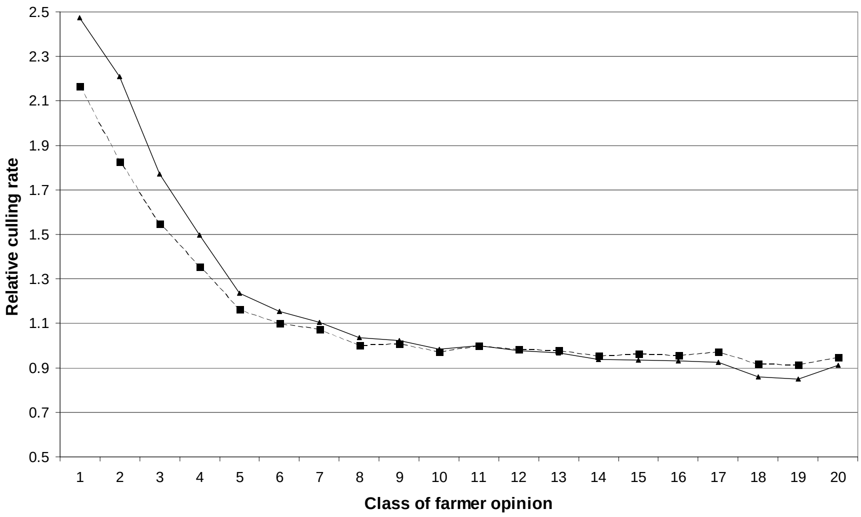

Figure 2. *Relative culling rate across different classes of farmer opinion for true (– ▲ –) and functional (--■--) longevity.*

The risk of culling for different classes of farmer opinion is shown in Figure 2. This figure is typical of all farmer scored type traits with an observed pattern of diminishing returns as the score increased. Cows in the strongly undesirable classes (>2 SD below the mean) were at a higher risk of being culled compared to cows of intermediate scores, but cows with high scores appeared to confer no additional advantage in their ability to avoid voluntary and involuntary culling.

Based on the relative culling rates for udder overall, cows with a high probability of being culled tended to exhibit lower scores corroborating previous international results on mammary traits (Schneider et al., 2003); similar trends were observed for stature, udder support, fore udder attachment, rear udder height, and dairy conformation. Legs showed an opposite trend with high scoring cows (i.e., more sickled legs) being at greater risk of being culled; this trend was obvious for both true longevity and functional longevity. Legs measured in New Zealand is a similar trait to rear legs, side view or rear legs set reported in some studies (Short and Lawlor, 1992; Larroque and Ducrocq, 2001; Schneider et al., 2003). Capacity, rump angle, rump width and front and rear teat placement exhibited an intermediate optimum with an increased risk of being culled in cows at both extremes.

4.2 Change in linear type traits in Ireland

A significant ($P<0.05$) linear trend existed across years for nine out of the 17 type traits (Table 1) analysed across both data sets including: stature (STA; Figure 3), angularity (ANG), fore-udder attachment (FUA), rear-udder height (RUH), udder support (US), udder-depth (UD; entire dataset only), teat position side view (TPS), temperament (TEMP) and ease of milking (EASE). All regression coefficients were positive with the exception of udder depth which was negative implying that udders had become deeper over time. On average animal stature increased annually by 0.07 units, or in other words by 0.7 units since 1995. This has repercussion for optimal cubicle and milk parlour design. The strong trend towards more angular cows with time is a consequence of the upgrading of the traditional British Friesian to Holstein; the latter breed being more aggressively selected for higher milk yield simultaneous with greater angularity. There has been a significant trend over the past decade in Irish Holstein-Friesian dairy cows towards tighter fore udder attachments, deeper udders but with stronger support, which has implications for udder health and functional longevity. This is concurrent with an increase in the distance between the teats when viewed from the side, despite its intermediate optimum. This may have repercussion for the suitability of animals, long term, to automatic milking as well as impacting on milking time and udder health. Furthermore, animals in Ireland have become more docile and faster milking over the past decade.

There was no significant annual linear trend in the set of the rear legs when viewed from the side, or in the angle of the foot which is owing to their intermediate optima.

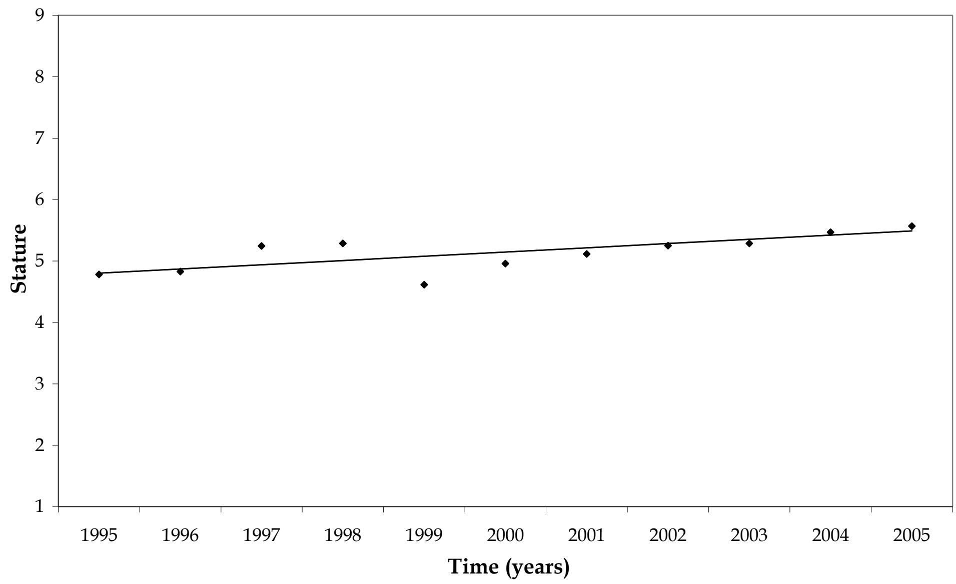

Figure 3. Change in cow stature (measured on a scale of 1 to 9) observed between 1995 and 2005, with fitted regression line.

Table 1. Measurement scale, least squares means for the first year (1995) and last year (2005) of study, and linear regression coefficient (b) for the type traits that changed significantly (P<0.05) over time using the entire dataset.

Trait	Score	Mean		b+
	1-9	1995	2005	(x100)
STA	130cm-154cm	4.8	5.6	6.92
ANG	Coarse-sharp	5.1	5.4	4.50
FUA	Loose-tight	4.7	5.2	5.77
RUH	Very low-very high	5.0	5.6	7.51
US	Broken-strong	5.7	5.8	5.05
UD	Below-above hocks	5.7	5.5	-4.76
TPS	Close-apart	5.0	5.3	4.44
TEMP	Nervous-quiet	4.1	6.4	21.99
EASE	Slow-fast	3.7	6.1	22.45

+Standard errors ranged from 0.03 to 0.04.

4.3 Phenotypic and genetic parameters for type traits in Ireland

Mean, genetic standard deviation, coefficient of genetic variation and heritability estimates for the various type traits are summarized in Table 2. Heritability estimates and coefficients of genetic variation were in general largest in the body and teat related type traits. The heritability of the body and dairy composite traits was also large (0.40 and 0.45, respectively). In contrast the management traits (i.e., ease of milking and temperament) expressed some of the lowest heritability and coefficient of variation estimates. The coefficient of genetic variation across all composite traits was also small suggesting little genetic variation. The feet and leg related traits were also lowly heritable (0.06 to 0.14). Heritability estimates reported in the present study were in general agreement with most previous international reports (Short and Lawlor, 1992; Brotherstone, 1994; Cue et al., 1996; Pryce et al., 2000). However, few heritability estimates are available in the literature for udder texture and bone quality.

Mean milk yield and the genetic variation in milk yield increased with parity (Table 3); an opposite trend was observed for calving interval. The proportion of cows surviving from one parity to the next decreased with increasing parity while there was no obvious trend in the change in genetic variation. The lowest coefficient of genetic variation was observed for calving interval while the highest was observed for milk yield. Heritability estimates reported in the present study are in agreement with previous international estimates, using linear models, for milk yield (Pryce et al., 1998; Kadarmideen, 2004), calving interval (Pryce et al., 1998; Haile-Mariam et al., 2004), survival (Short and Lawlor, 1992; Cue et al., 1996; Haile-Mariam et al., 2004), and lifespan (Brotherstone et al., 1998).

Table 2. Trait definition, number of records, mean, genetic standard deviation (σ_g), heritability (h^2) estimates† and genetic coefficient of variation (CVg) for the type traits included in the analysis.

Trait	Definition	No. records	Mean	σ_g	h^2	CVg
Stature	Small - Tall	47431	5.9	0.77	0.46	13%
Chest width	Narrow - Wide	47431	5.2	0.66	0.25	13%
Body depth	Shallow - Deep	47431	5.9	0.64	0.35	11%
Angularity	Coarse - sharp	47431	5.9	0.68	0.35	12%
Body condition score	Thin - Fat	42581	4.6	0.63	0.20	14%
Rump angle	High pins - low pins	47431	4.1	0.64	0.31	16%
Rump width	Narrow - Wide	47431	5.3	0.52	0.19	10%
Fore-udder attachment	Loose - Strong	47431	5.4	0.52	0.17	10%
Rear udder height	Very low - Very high	47431	5.8	0.59	0.23	10%
Udder support	Flat - Strong	47431	6.0	0.42	0.13	7%
Udder depth	Below hocks - Above hocks	47431	5.5	0.61	0.28	11%
Udder texture	Coarse - Silky	29591	5.9	0.46	0.17	8%
Rear teat placement	Apart – Close	20143	5.7	0.65	0.20	11%
Teat position, rear view	Outside - Close	47431	4.6	0.62	0.23	13%
Teat position, side view	Close - Apart	47431	5.7	0.56	0.25	10%
Teat length	Short - Long	47431	4.7	0.70	0.32	15%
Foot angle	Low - Steep	47431	5.2	0.39	0.11	7%
Rear legs set	Straight - Sickled	47431	5.5	0.41	0.14	8%
Bone quality	Coarse - Fine	29598	6.3	0.49	0.21	8%
Locomotion	Lame - Even gait	46324	5.0	0.25	0.06	5%
Temperament	Nervous - Quite	42304	5.6	0.18	0.03	3%
Ease of milking	Slow - Fast	42304	5.4	0.13	0.02	2%
Dairy composite	Poor – Excellent	47431	80.9	3.48	0.45	4%
Body composite	Poor – Excellent	47431	79.2	3.32	0.40	4%
Legs composite	Poor – Excellent	47431	79.3	1.76	0.14	2%
Udder composite	Poor - Excellent	47431	78.3	2.77	0.21	4%

†Standard error of the heritability estimates were all less than 0.033.

Table 3. Number of records, mean, genetic standard deviation (σ_g), heritability (h^2) estimates† and coefficient of genetic variation (CVg) for milk, survival and calving interval for the first three parities as well as overall lifespan.

	Trait	No. records	Mean	σ_g	h^2	CVg
Parity 1	Milk	200,589	5273	442.9	0.31	8%
	Survival	184,376	0.84	0.039	0.01	5%
	Calving interval	151,314	393	12.3	0.03	3%
Parity 2	Milk	143,154	6004	491.1	0.30	8%
	Survival	131,158	0.83	0.054	0.02	7%
	Calving interval	107,193	389	11.8	0.03	3%
Parity 3	Milk	105,395	6381	506.8	0.28	8%
	Survival	96,462	0.82	0.043	0.01	5%
	Calving interval	77,415	386	7.8	0.02	2%
	Lifespan	200,589	3.27	0.119	0.06	4%

†Standard error of the heritability estimates for milk yield, calving interval and survival across all three parities were all less than 0.019, 0.005 and 0.004, respectively

4.3.1 Genetic correlations

The sign of the correlations with milk production across the first three parities was consistent for all type traits with the exception of teat length where the correlations were all near zero (Table 4). Taller, narrower, more deeper bodied, angular cows had higher genetic merit for milk production. This was reflected also in the moderate positive genetic correlations between the body and dairy composite traits and milk yield. Strongly supported udders with superior fore udder attachment and deeper, more silky udders with higher rear udder height were predisposed to a higher genetic merit for milk yield. Once more this was reflected in a positive correlation between udder composite and milk yield across all three parities. A negative correlation was evident between foot angle and milk yield while the correlations between the remaining feet and legs related traits and milk yield were weak.

Table 4. Genetic correlations between type traits and milk yield in the first three parities

Trait	Parity 1	Parity 2	Parity 3
Stature	0.13*	0.19*	0.16*
Chest width	-0.14*	-0.17*	-0.01
Body depth	0.08	0.15*	0.16*
Angularity	0.45*	0.47*	0.33*
Body condition score	-0.28*	-0.31*	-0.16*
Rump angle	0.10	0.09	0.14*
Rump width	0.00	0.02	0.08
Fore-udder attachment	-0.24*	-0.23*	-0.23*
Rear udder height	0.21*	0.22*	0.12
Udder support	0.17*	0.17*	0.10
Udder depth	-0.38*	-0.30*	-0.27*
Udder texture	0.37*	0.42*	0.27*
Rear teat placement	0.17	0.22*	0.03
Teat placement, rear	0.15*	0.09	0.16*
Teat placement, side	0.34*	0.27*	0.24*
Teat length	0.08	0.06	-0.03
Foot angle	-0.16*	-0.15*	-0.13
Rear legs set	0.17*	0.17*	0.10
Bone quality	0.12	0.19*	0.00
Locomotion	-0.02	-0.07	-0.12
Temperament	0.23*	0.02	0.14
Ease of milking	0.38*	0.31*	0.22
Dairy composite	0.41*	0.45*	0.36*
Body composite	0.11*	0.20*	0.21*
Udder composite	0.23*	0.23*	0.21*
Legs composite	-0.05	-0.04	0.00

* Absolute correlations are greater than two standard errors from zero.

The sign of the genetic correlations between most of the body traits and milk yield are in general agreement with previous literature across alternative breeds of cattle (Meyer et al., 1987; Harris et al., 1992; Misztal et al., 1992; Short and Lawlor, 1992; Brotherstone, 1994). In agreement with previous results across most studies and breeds, one of the strongest absolute genetic correlation between milk yield and a linear type trait existed for dairy character (Visscher and Goddard, 1996), dairy form

(Harris et al., 1992; Misztal et al., 1992; Short and Lawlor, 1992; DeGroot et al., 2002) or angularity (Brotherstone, 1994), all of which represent similar cow characteristics. Genetic correlations between udder depth and milk yield and between udder support and milk yield are in general agreement with previous literature (Meyer et al., 1987; Misztal et al., 1992; Short and Lawlor, 1992; Brotherstone, 1994) whereby udder cleft scored in the US is assumed to be a similar trait to udder support scored in Ireland. However, the strength of the correlations in the present study tended to be weaker for udder depth and stronger for udder support compared to other studies. Such differences may be explained through differences in trait definition across countries or time but may also be a function of differences in farmer selection intensity for greater udder support simultaneous with high milk yield because of the expected benefits of improved udder support for reduced incidence of mammary related diseases or indicators of disease (DeGroot et al., 2002). The negative correlation between udder depth and milk yield is mediated through the greater volume capacity of deeper udders. The negative correlation between milk yield and fore udder attachment is likely a function of the greater milk weight progressively weakening the attachment of the fore udder. The authors are unaware of any previous literature that cited genetic correlations between udder texture and milk yield in Holstein dairy cows. Results from the present study suggest that cows with silkier udders exhibit a higher genetic merit for milk yield.

Genetic correlations between the feet and legs related traits and milk production suggest genetically higher milk producers have lower foot angles, tend to be more prone to a greater degree of lameness and have a finer bone quality. Previously reported genetic correlations between foot angle and milk production are all near zero (Meyer et al., 1987; Misztal et al., 1992; Short and Lawlor, 1992; Brotherstone, 1994). Genetic correlations between calving interval across the first three parities and type traits are outlined in Table 5. The range in correlations with calving interval across parities changed little within type trait. The most obvious exception was rear teat placement which was positively correlated with calving interval in first and second parity animals (0.17 to 0.20) and negatively correlated with calving interval in third parity (-0.18); however, none of the absolute correlations were greater than zero plus twice their respective standard error. In general, the sign of the correlations between the type traits and calving interval was consistent with the sign of the correlations between the same type trait and milk yield. This may be partly attributable to the positive correlation between milk yield and calving interval (0.53 to 0.89), both of which were always included in the multivariate analyses thereby ensuring the correlation matrix was positive definite.

Table 5. Genetic correlations between type traits and calving interval in the first three parities

Trait	Parity 1	Parity 2	Parity 3
Stature	0.15	0.05	0.01
Chest width	-0.16	-0.27*	-0.13
Body depth	0.23*	0.14	0.19
Angularity	0.46*	0.48*	0.41*
Body condition score	-0.35*	-0.39*	-0.21
Rump angle	-0.08	-0.13	0.09
Rump width	0.11	-0.02	-0.28*
Fore-udder attachment	-0.08	-0.24*	-0.42*
Rear udder height	0.20*	0.25*	0.07
Udder support	0.28*	0.29*	0.10
Udder depth	-0.15	-0.21*	-0.34*
Udder texture	0.51*	0.48*	0.35*
Rear teat placement	0.20	0.17	-0.18
Teat placement, rear	0.31*	0.17	0.01
Teat placement, side	0.23*	0.21*	0.34*
Teat length	0.01	0.02	0.10
Foot angle	0.11	-0.01	-0.30
Rear legs set	-0.16*	0.00	0.02
Bone quality	0.38*	0.40*	0.14
Locomotion	0.21	0.03	-0.05
Temperament	0.56*	0.38*	0.18
Ease of milking	0.04	0.07	-0.01
Dairy composite	0.44*	0.41*	0.46*
Body composite	0.15	0.10	0.10
Udder composite	0.43*	0.28*	0.20
Legs composite	0.11	0.07	0.10

* Absolute correlations are greater than two standard errors from zero.

Literature investigating the genetic associations between type traits (other than body condition score) and calving interval are few; analyses based on multiparous animals are fewer still. Additionally, most genetic correlation estimates between type traits (excluding body condition score) and calving interval in the literature are inferred from the relationship among calculated sire predicted transmitting abilities for the respective traits (Dadati et al., 1986; Royal et al., 2002; Haile-Mariam et al., 2004) and generally those that used variance component estimation by REML to estimate correlations directly only included fertility data from pedigree animals or on a small number of non-pedigree animals (Pryce et al., 2000; Wall et al., 2005). In the present study possible bias accruing from deliberately delaying the interval to service, and thus the subsequent calving interval, in cows of perceived superior type was minimised by not including information on calving interval for cows with type information. The results reported herein are more likely to reflect the true influence of linear type traits on calving interval.

The strongest genetic correlations with calving interval were observed for angularity, body condition score, udder texture, temperament and the dairy and udder composite. These associations with calving interval may be partly accounted for by the correlations between each of the aforementioned traits with milk yield. Nevertheless, Figure 1 illustrates that not all of the relationship between angularity and calving interval can be explained by the association between angularity and milk yield and suggests an additional benefit of including angularity in a sub-index for predicting genetic merit for calving interval. Haile-Mariam et al. (2004) deduced similar conclusions from their analysis which is in agreement to a lesser degree with results from the US (Rogers et al., 1999) where an unfavourable correlation between dairy form adjusted for milk yield and reproductive diseases was reported. Body condition score was negatively associated with calving interval suggesting superior fertility in animals with higher body condition score which corroborates previous studies from Europe (Pryce et al., 2000; Veerkamp et al., 2001), The United States (Dadati et al., 1986; Dechow et al., 2004) and Australasia (Haile-Mariam et al., 2004; Harris and Pryce, 2004).

Angularity is the main contributing type trait to the dairy composite and the positive correlation with calving interval agrees with Dadati et al. (1986) and Dechow et al. (2004) who both reported a genetic correlation of 0.38 between dairy form/character (a trait similar to angularity) and days open/calving interval in US Holsteins. Days open is expected to be highly correlated with calving interval because of the part-whole relationship between them. Similar correlations were observed between angularity and calving interval in the UK (Pryce et al., 2000) and Australia (Haile-Mariam et al., 2004).

In agreement with previous research (Dadati et al., 1986; Pryce et al., 2000; Royal et al., 2002), there was a tendency for cows with genetically more shallow, weaker udders to have shorter calving intervals. Dadati et al. (1986) speculated that this may be partly attributed to their genetic relationship with milk yield. Correlations between rump and calving interval were generally weak corroborating previous international studies (Dadati et al., 1986; Pryce et al., 2000; Haile-Mariam et al., 2004; Wall et al., 2005).

The strongest absolute correlations with calving interval across parities were observed for angularity, body condition score, udder texture, and the dairy and udder composite traits; most of these correlations differed from zero by over twice their respective standard error. Genetically these are very similar traits with genetic correlations between all five traits ranging from 0.69 to 0.98. More angular cows with silky udders had longer calving intervals. Positive correlations were also observed between bone quality and calving interval suggesting genetically longer calving interval in the daughters of sires with fine bone quality. Figure 4 illustrates that not all of the relationship between angularity and calving interval can be explained by the association between angularity and milk yield and suggests an additional benefit of including angularity in a sub-index for predicting genetic merit for calving interval. Haile-Mariam et al. (2004) deduced similar conclusions from their analysis which is in agreement to a lesser degree with results from the US (Rogers et al., 1999) where an unfavourable correlation between dairy form adjusted for milk yield and reproductive diseases was reported.

The genetic correlations between true and functional survival and the different type traits are summarised in Table 6. A large proportion of the correlations were not significantly different from zero as determined by twice the standard error of the correlation. There was a general tendency for the strength of the absolute correlation between type and functional survival to be strongest in parity three suggesting an increased importance of superior type as the animal gets older. Although the correlation between most type traits and survival changed little following adjustment for differences in milk yield there were some notable exceptions. Body depth, rump width and udder depth exhibited a stronger genetic correlation with functional survival than with true survival signifying their greater association with the innate genetic ability of an animal to delay involuntary culling. Type traits moderately correlated with milk yield such as angularity, udder texture and dairy composite although also moderately correlated with true survival were poorly correlated with functional survival. In some instances the sign of the correlation with survival changed following adjustment for differences in milk yield.

In general, the correlations between each of the linear type traits and true or functional lifespan were similar to the correlations between the linear type traits and true and functional survival, respectively from third to fourth lactation. However, angularity was negatively correlated with true lifespan despite positive correlations existing with survival to second, third and fourth lactation; a stronger negative correlation between angularity and lifespan was evident than observed between angularity and survival from third to fourth lactation.

Table 6. Genetic correlations between type traits and true and functional survival in the first three parities

	True survival			Functional survival		
Trait	Parity 1	Parity 2	Parity 3	Parity 1	Parity 2	Parity 3
Stature	-0.09	0.10	-0.04	-0.21*	0.01	-0.19
Chest width	-0.23*	-0.21*	-0.37*	-0.18	-0.14	-0.47*
Body depth	-0.32*	-0.16	-0.23	-0.45*	-0.26*	-0.44*
Angularity	0.17	0.20*	0.21	-0.12	-0.03	-0.02
Body condition score	-0.10	-0.18	-0.41*	0.08	-0.03	-0.39*
Rump angle	0.11	0.18	0.34*	0.06	0.15	0.31*
Rump width	-0.19	-0.16	-0.10	-0.23*	-0.18	-0.23
Fore-udder attachment	-0.10	-0.04	0.03	0.04	0.07	0.25
Rear udder height	0.10	0.20	0.03	-0.03	0.11	-0.07
Udder support	0.14	0.02	-0.02	0.05	-0.06	-0.11
Udder depth	-0.06	0.10	0.08	0.20	0.27*	0.35*
Udder texture	0.29*	0.22	0.38*	0.09	0.03	0.23
Rear teat placement	0.10	0.12	0.38	-0.01	0.02	0.44*
Teat placement, rear	0.09	-0.02	0.23	0.00	-0.07	0.16
Teat placement, side	0.17	0.06	0.09	-0.04	-0.07	-0.10
Teat length	0.03	0.06	-0.11	-0.03	0.03	-0.12
Foot angle	-0.05	-0.11	-0.23	0.05	-0.04	-0.18
Rear legs set	-0.02	-0.08	0.08	-0.15	-0.18	0.01
Bone quality	-0.01	0.04	0.20	-0.09	-0.05	0.25
Locomotion	0.07	-0.04	-0.10	0.10	0.00	-0.03
Temperament	0.09	-0.15	0.01	-0.06	-0.17	-0.11
Ease of milking	0.37	0.78*	-0.01	0.18	0.69*	-0.20
Dairy composite	0.11	0.19*	0.22	-0.16	-0.02	-0.04
Body composite	-0.22*	0.01	-0.02	-0.35*	-0.09	-0.21
Udder composite	0.08	0.22	0.31*	-0.07	0.12	0.21
Legs composite	0.10	0.15	-0.11	0.15	0.19	-0.15

* Absolute correlations are greater than two standard errors from zero; standard errors of correlations with functional survival are assumed to be the same as those with true survival

As expected, the greatest change in genetic correlations between the type traits and true or functional survival was observed across the type traits that were most strongly correlated with milk yield. For example, angularity was positively correlated with true survival (0.17 to 0.21) but negatively correlated with functional survival (-0.12 to –0.02); the genetic correlation between angularity and milk yield across parities varied from 0.33 to 0.47.

Table 7. Genetic correlations between type traits and true and functional lifespan

Trait	True Lifespan	Functional lifespan
Stature	-0.14*	-0.18*
Chest width	-0.28*	-0.25*
Body depth	-0.41*	-0.45*
Angularity	-0.01	-0.14*
Body condition score	-0.14	-0.07
Rump angle	0.20*	0.17*
Rump width	-0.28*	-0.29*
Fore-udder attachment	0.04	0.11
Rear udder height	0.09	0.04
Udder support	-0.05	-0.10
Udder depth	0.21*	0.32*
Udder texture	0.18	0.07
Rear teat placement	-0.14	-0.19
Teat placement, rear	-0.03	-0.07
Teat placement, side	0.02	-0.08
Teat length	-0.19*	-0.22*
Foot angle	-0.12	-0.08
Rear legs set	-0.05	-0.10
Bone quality	0.10	0.07
Locomotion	-0.04	-0.03
Temperament	0.03	-0.04
Ease of milking	0.30	0.20
Dairy composite	-0.04	-0.16*
Body composite	-0.29*	-0.33*
Udder composite	0.12	0.06
Legs composite	0.02	0.03

* Absolute correlations are greater than two standard errors from zero; standard errors of correlations with functional lifespan are assumed to be the same as those with true lifespan

The consistency in sign of the correlations between the various type traits and survival to a given parity or lifespan corroborates results reported by Rogers et al.

(1991) in US Jerseys where the sign of the genetic correlation between type traits and first lactation survival or length of production life up to 60 months of age were consistent. Rogers et al. (1989) showed a similar trend in sign of correlation between type trait and survival to 48, 54 and 84 months of age or age at last record. This suggests that the directional impact of type traits on survival to different ages is consistent although the strength of the relationship may vary.

The correlations reported in the present study between body related type traits and lifespan are in contrast to those reported by Brotherstone et al. (1998) in UK pedigree Holstein-Friesian animals. Brotherstone et al. (1998) reported genetically longer lifespan in taller, deeper animals with high, wide pins. The correlation between foot angle and survival/lifespan in the present study was negative or close to zero implying that a steeper foot angle had poorer survival; this disagrees with Brotherstone et al. (1998) who reported a longer lifespan in cows with steeper foot angles. Opposite signs were also evident when comparing the genetic correlations between udder support and lifepan in the present study with reports from Brotherstone et al. (1998). However, the signs of the correlations between the type traits common to the Irish and New Zealand type classification schemes and survival to second lactation are in general agreement with each other with the exception of the capacity of the animal measured as body depth and chest width in Ireland and as capacity in New Zealand (Cue et al., 1996); nevertheless, the genetic correlation between most of the inspector scored type traits in New Zealand and survival were not significantly different from zero. Narrower, shallower animals had a greater probability of survival in Ireland while the correlation between capacity and survival in New Zealand Holstein-Friesians, although not significantly different from zero was positive (Cue et al., 1996).

Several factors may contribute to discrepancies between the associations with survival reported in the present study and previous international reports. Firstly, the dairy production system in Ireland is predominantly based on grazed grass. Cows in Ireland are outdoors for the vast majority of the year and thus one may speculate that the influence of type traits on an outdoor system of milk production may differ to the impact in confinement systems. Secondly, survival as defined in the present study was measured in non-pedigree (i.e., grade animals). Several researchers (Short and Lawlor, 1992; Dekkers et al., 1994) have previously show different relationships between type traits and survival in different herd types. Thirdly, the lower lactation milk production in the present study cows compared to those in the United States (Dechow et al., 2002) and some European countries (Pryce et al., 1998; Pérez-Cabal and Alenda, 2002; Kadarmideen, 2004) may alter the strength and direction of the relationship between type traits and survival. Boettcher et al. (1997) reported differences in the relationships between some type traits and survival in different herd-year-season production levels in grade herds.

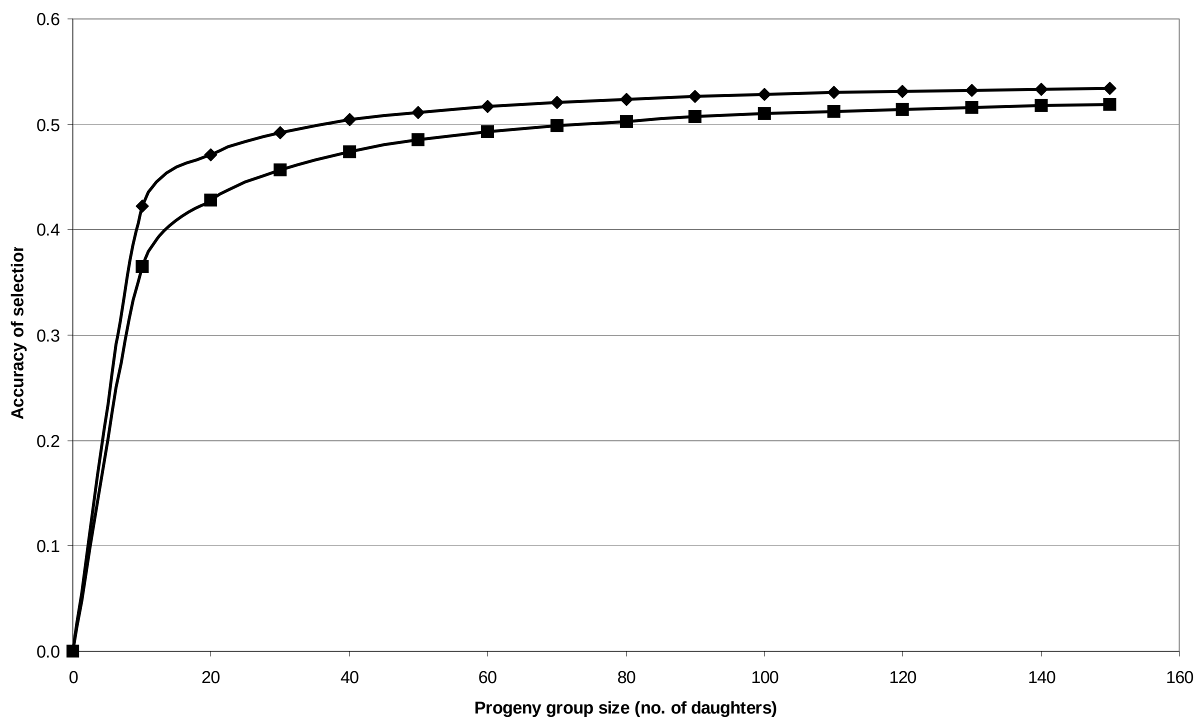

Figure 4. Accuracy of selection on calving interval in parity one animals when the selection index includes parity one milk yield only (-■-) or milk yield and angularity (-♦-) across different progeny group sizes.

4.4 Farmer satisfaction

The heritability for farmer satisfaction was 0.13 (SE=0.051) indicating that 13% of the phenotypic variation in satisfaction of cows across 316 Irish herds was due to additive genetic effects. The heritability of 0.13 corroborates previous estimates on similar traits in New Zealand (0.12; Cue *et al.*, 1996) and Australia (0.18 to 0.23; Visscher and Goddard, 1995). Genetic correlations with milk production were similar in sign although stronger than the corresponding phenotypic correlations with higher milk production associated with more favoured animals (Table 8). Interestingly, the correlations with milk composition were negative suggesting that farmers were more satisfied with animals that had lower milk composition. This is at odds with expectations and attempts will be made in the future to try and explain this phenomenon. One potential reason could be the association between milk composition and some trait of importance to Irish farmers that is currently not measured or analysed. Although the standard errors were relatively large, there was a general tendency for farmers to be more satisfied with animals of better udder health. A positive, although weak, correlation (r=0.07; P<0.05) existed between farmer satisfaction and economic breeding index indicating that farmers were more satisfied with animals scoring high on the Irish dairy cattle total merit index. Furthermore, a stronger positive correlation (r=0.27; P<0.001) between farmer satisfaction and overall type was evident indicating that conformation was also an important characteristic of a cow in the eyes of the farmer. Farmers tended to favour taller, wider, deeper, more angular animals with silky, well supported and attached udders and that walked with an even gait.

Table 8. Phenotypic and genetic correlations (standard errors in parenthesis underneath) between farmer satisfaction and milk production and composition.

Trait	Milk yield	Fat yield	Fat percent	Protein yield	Protein percent	SCS
Phenotypic	0.33 (0.020)	0.20 (0.022)	-0.15 (0.023)	0.31 (0.021)	-0.12 (0.023)	-0.04 (0.023)
Genetic	0.55 (0.204)	0.26 (0.314)	-0.28 (0.216)	0.40 (0.224)	-0.25 (0.206)	-0.06 (0.289)

5. CONCLUSIONS AND IMPLICATIONS

- Farmer opinion of the cow was most strongly associated with true and functional longevity. Previous genetic analyses by others (Cue et al., 1996) suggest a moderate genetic heritability for this trait with a moderate genetic association with survival. Of the individual type traits describing the physical characteristics of the cow, the udder related traits had the largest effect on functional longevity.

- Results from this study suggest some similarity among Irish farmers in factors affecting their overall satisfaction, as indicated by the existence of a heritability of 0.13. It is therefore feasible to produce estimated breeding values for sires for overall farmer satisfaction. Farmers tended to be more satisfied with cows of superior economic breeding index and overall type. Early predictors can be derived in a multi-trait analysis including traits such as milk production that are genetically correlated with farmer satisfaction. It may also be possible to derive conversion equations for farmer satisfaction in Ireland based on proofs for milk production and/or type in other countries.

- Results from the present study, albeit on a somewhat biased sample, suggest that animals are getting taller which has repercussions for optimal cubical and milking parlour design. Animals also have developed deeper, more strongly supported and attached udders which has negative implications for udder health. Furthermore, animals have tended to become more docile and faster milking, which has both management and welfare benefits.

- Results from the present study clearly identify moderate relationships between some type traits and milk yield, calving interval, and true and functional survival and lifespan. Taller, wider, deeper more angular cows with deep udders tended to produce more milk but had genetically inferior fertility and survival. Harnessing the predictive capabilities of a select number of type traits as genetic predictors for calving interval and survival will facilitate more accurate identification of genetic merit for sires for calving interval or survival, especially in sires with a few number of daughters producing in Ireland.

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