Comparison of associations between estimated breeding values and cow survival in herds being milked once or twice a day

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Abstract

The objective of this study was to investigate the link between estimated breeding values (EBV) for selected traits, including Traits Other than Production (TOP), and cow survival in herds milked once-a-day (OAD), and to contrast with herds milked twice-a-day (TAD). After filtering, data from 234 OAD herds (71,321 cows) and 234 TAD herds (75,123 cows) were extracted from the Dairy Industry Good Animal Database between 2007 and 2021. Cow survival from parities 1 to 2, 2 to 3, 3 to 4, 4 to 5 and 5 to 6 (S12, S23, S34, S45 and S56) were modelled within each milking frequency and age parity group, with trait EBVs fitted as covariables and the fixed effect of herd-year, using a generalised linear model with a gaussian kernel. The survival rate in OAD cows was higher than in TAD cows in S12 and less in S34 to S56. Udder support EBV became important in older cows (S45 and S56) but there were no significant differences between OAD and TAD herds. Compared to OAD herds, Fertility EBV had a greater effect on survival in TAD herds up to S34, as did Body Condition EBV for S12. Conversely, milk Volume, Fat, Protein and Somatic Cell Score EBVs had smaller effects on survival in TAD herds. Our results do not contain evidence that warrant greater selection pressure on functional traits in OAD systems relative to TAD to enhance animal survival. When selecting sires, selection pressure could be reduced on some traits, such as Fertility and Body Condition, in OAD systems, with a greater emphasis placed on production and milk composition.

Keywords: breeding value; survival; milking frequency; once-a-day milking

Introduction

Attracting, retaining and growing the on-farm workforce is a key goal for the New Zealand dairy sector (DairyNZ 2022a). To achieve this goal 'changing the job' is one initiative that aims to reduce the reliance on people and make on-farm work more attractive. Milking is a time-consuming task in pastoral dairy systems, averaging about 19 h/week/worker at peak lactation for an average herd size of 407 cows, excluding time spent herding cows and cleaning the dairy (Edwards et al. 2020). Additionally, in many cases, the timing of milkings influences start and finish times of the day and determines when non-milking tasks can be carried out. Consequently, milking is an obvious task to focus on to both reduce the number of hours worked but also increase the flexibility of the job.

Within a dairy system farmers can select firstly the number of milkings and secondly the timing of those milkings. Use of extended milking intervals such as milking three times in two days (Edwards et al. 2022), variations to this schedule such as milking ten times in seven days, and once-a-day (OAD) milking (Clark et al. 2006) can reduce the amount of time spent milking and on other associated tasks as well as giving the ability for milking to occur at different times of the day compared with twice-a-day (TAD) milking. This increases the flexibility of the job, enabling different start and end times as well as the ability to schedule non-work activities at any time during the day without having to find cover. Of these different milking schedules OAD provides the greatest reduction in milking time ~9.5 h/worker/week less than TAD at peak lactation (Edwards et al. 2020), as well as allowing for milking to occur at any time during the day.

Previous research has indicated that that there is a variation in the response to extended milking intervals between cows (Clark et al. 2006; Holmes et al. 1992; Woolford et al. 1985), although the significance of this for breeding programmes is debated (Lembeye et al. 2017; Lembeye et al. 2021; Stachowicz et al. 2014). Nevertheless, it is clear there are differences in sire selection and culling decisions between herds milked OAD and TAD, with fewer animals culled due to reproductive performance and more for low production and udder related reasons in OAD herds despite a similar overall replacement rate (Edwards 2018). Furthermore, there are logical reasons why there could be differences in the importance of physical confirmation traits between OAD and TAD, for example, due to the stressors of a greater volume of milk within the udder of cows milked OAD. In response to farmer requests, commercial breeding companies in New Zealand currently place additional emphasis on milking speed, body capacity, front teat placement, udder support, protein and somatic cell score when identifying bulls suited to OAD herds.

Estimated breeding values (EBVs) for traits other than production (TOP), derived mostly from records on daughters in TAD herds, can be used to improve physical confirmation in OAD systems (Sneddon et al. 2019). Further, associations have been identified between adaptability to milking, overall opinion and leg conformation and the survival of cows in one herd milked OAD (Rocha et al. 2017).

The primary goal of this study was to explore whether there are differences in the relationships between EBVs for production, health and TOP and cow survival between herds milked OAD and TAD using data from commercial herds in New Zealand. Knowledge of these relationships will be useful to farmers transitioning to OAD milking by identifying cows with attributes that decrease the likelihood of survival so they can be culled/sold/not bred from. Further, this knowledge could be used to determine the value of TOP traits in OAD systems allowing for the creation of an OAD selection index with an economic basis. Enhanced selection could minimise the number of cows removed due to low production and udder related reasons, enabling farmers milking OAD to take advantage of the improved reproductive performance and reduce replacement rate with its associated benefits for farm profitability and greenhouse gas footprint.

Materials and methods

Phenotype data were collated from the New Zealand Dairy Industry Good Animal Database (DIGAD; DairyNZ, Hamilton, New Zealand) under access panel request #128, and genomic breeding values (GEBV; to contrast whether genomic estimated breeding values of TOP traits might provide a stronger prediction of survival response than conventional pedigree based EBVs) were provided by the Livestock Improvement Corporation (LIC; Hamilton, New Zealand). Permission was granted from LIC to access non-core milking regime codes and EBVs located in DIGAD. The initial dataset contained spring calving cows that entered herds after 1st June 2007, and herd test records between 1st June 2007 to 31st May 2021.

The milking frequency of a herd was defined based on the sequence of herd test-season-herd levels. Season was defined 1-Jun to 31-May of the following calendar year, e.g. the 2008-2009 season was between 1st June 2008 and 31st May 2009. The first classification was determined by milking regime code. A milking regime code (AM/PM sample, AM only TAD, PM only TAD and OAD) is assigned to each cow at each herd test or milk recording event, which typically occurs four times annually. If ≥95% of the tested cows in the herd at a recording event were coded as being milked OAD, then the herd was classified as being OAD at that test. Similarly, if ≥95% of the cows at a herd test were coded milked TAD, then the herd was classified as being TAD at that test. All the remaining herds were coded as "unclassified". Next, the herd milking frequency for each season was defined based on all the herd test milking frequencies within the season. Between 1-Jun and 1-Jan if all the herd test milking frequencies were consistent throughout that period, i.e. all OAD or all TAD, then the herd received that classification for that season. Additionally, if all the herd tests between 1-Jun and 1-Jan were classified as TAD, but after 1-Jan were OAD, then the herd was coded as TAD at that season (i.e. milked TAD at peak lactation). If the herd test milking frequencies were a mix of TAD or OAD before 1-Jan, or TAD herd tests occurred after OAD herd tests, then the herd was coded as "unclassified" for that season. Lastly, the final herd milking frequency was defined by the sequence of milking frequencies across seasons. Herds with consistent OAD or TAD across all seasons were coded as OAD or TAD and herds that changed from TAD to OAD were coded as "transition". If TAD occurred after OAD, or "unclassified" existed, the herds were then coded as "unclassified".

Six survival traits were computed for each cow at each consecutive parity period, i.e. S12 for the survival between the 1st and 2nd parities, until S56 for the survival between the 5th and 6th parities.

Data filtering

Herds were removed if there was a missing year in herd tests; had fewer than 3 herd tests across all milking seasons; unclassified herd milking frequency classification. To ensure uniformity across TAD and OAD herds and eliminate the potential confounding factors that can mask the trait effects on survival, additional filtering was applied to TAD herds: herds were removed if the herd size was greater than maximum OAD herd sizes during 2007-2021, if the herd had a monthly mean milk volume greater than that of the maximum cow mean volume from all OAD herds from 1-Sept to 31-Dec of each year, or if the herd had a level of foreign Holstein greater than 35% or with Holstein-Friesian greater than 40%. Individual animals were filtered out if they did not have parity survival information by 2021; if the transition year was not during parities 1-2 to 4-5 (S12-23 to S45-56); if there was a gap year in herd tests and if there were missing GEBV records. Results of transition herds were filtered out due to often insignificant results possibly caused by small number of observations (results not shown). There was a greater number of TAD herds (N=7,048) than OAD herds (N=234), so a random down sampling was used to select 234 TAD herds and thereby reduce the computation requirements.

Estimated Breeding Values

A wide range of EBVs were available, however, for this paper we have focused on Fertility, Functional Survival, Body Condition Score, Somatic Cell Score, Capacity, Front Teat, Milking Speed, Udder Support, Fat, Protein and Volume. Functional Survival is a composite trait containing effects from the EBVs for conformation of the legs, and udder as well as milking speed and body condition score. These indirect predictions are supplemented with actual survival records of female relatives, providing the herd carries out comprehensive recording of culling reasons. Cows which are culled for low milk production and for poor fertility, and their sires, are not penalised in the prediction of functional survival. For milk production traits (Fat, Protein, Volume), Somatic Cell Score, Fertility and Survival, a cows own performance records will have contributed to her estimated breeding values. For the remaining traits, information contributing to a commercial cow's EBV came from a relatively small number (40 to 80) of sire proving scheme daughters of her sire and maternal grand sire as these traits are not routinely recorded in commercial herds.

Statistical analyses

To evaluate the relationship between survival and

EBVs of interest, a linear regression was modelled for each trait. The analysis compared differences in the relationships between EBVs for production, health and TOP and cow survival between herds milked OAD and TAD. Firstly, all data were analysed using a single trait linear regression model. The survival equation was

$$y_{ijk} = \mu_{ijk} + CG_{ij} + \chi_{ijk} + \varepsilon_{ijk} \quad [1]$$

where y_{ijk} was the survival (1=survived and 0=culled/died/sold) of the *i*-th herd-year for *j*-th cow and *k*-th trait, μ was the mean, CG was the herd-year effect, χ was the EBV and ε was the error term. Ten models per EBV trait were run separately to each combination of five survival age groups and two herd milking frequencies. The coefficient solutions of the covariable effect χ were of interest here. Standardised coefficients, i.e. coefficient × standard deviations were reported in the results to simplify comparisons across traits with very different units.

To evaluate the effect of OAD or TAD on survival, an interaction term was added

$$y_{ijk} = \mu_{ijk} + CG_{ij.} + \chi_{ijk} + T_j \chi_{ijk} + \varepsilon_{ijk} \quad [2]$$

where $T_{j.}$ was the milking frequency effect for *j*-th cow, i.e. TAD=0 and OAD=1. Five models were run corresponding to each survival trait. The level of statistical significance of the $T\chi$ term was of interest here. All statistical analyses were operated in R v4.2 (R Core Team 2020, www.R-project.org).

Table 1 Number of herds and cows by age parity.

Age parity	Corresponding survival	N herd[1]		N cow[1]	
		TAD	OAD	TAD	OAD
2	S12	231	223	63,421	55,666
3	S23	214	223	52,364	50,426
4	S34	204	213	39,363	40,911
5	S45	188	205	29,395	32,297
6	S56	168	195	20,869	24,288

[1]Herds and cows overlap across age parities.

Results

After data cleaning and down sampling, the total number of herds milked TAD and OAD were 468 (234 herds in each system), while the total number of cows were 75,123 and 71,321, respectively. The breakdown of numbers of observations by age parity used in the modelling are shown in Table 1. The mean foreign Holstein breed percentage in OAD herd was slightly lower than TAD herds (13% vs. 17%, P<0.001), as were the mean Holstein-Friesian breed percentages (19% vs. 21%, P<0.05). Mean monthly cow milk production across the last 4 months of the calendar year was approximately 22% lower in OAD

Figure 1 Proportion of animals surviving in TAD (dark grey) and OAD (light grey) herds between 2007 and 2021 for S12 to S56, indicating survivals in parity 1-2 up to parity 5-6.

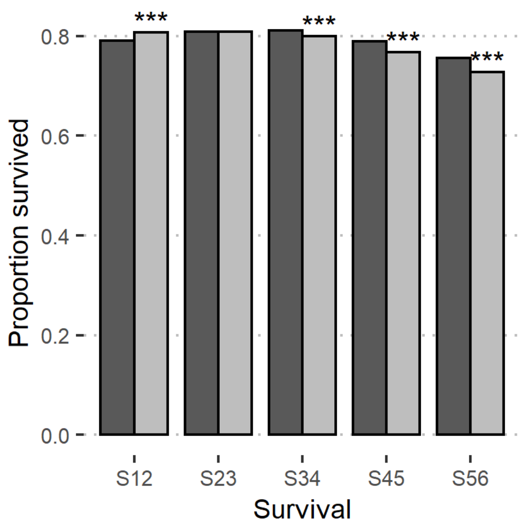


Table 2 Summary statistics of trait EBV in TAD and OAD herds[1].

Trait[2]	Unit	TAD			OAD			
		Mean	Median	SD	Mean	Median	SD	P value[3]
Body condition score	score	–0.015	–0.02	0.07	–0.018	-0.02	0.07	0.00
Functional survival	day	0.75	0.80	1.08	0.75	0.76	1.08	0.35
Somatic cell score	score	–0.02	–0.03	0.25	–0.04	-0.05	0.26	0.00
TOP capacity	score	0.13	0.05	0.22	0.12	0.06	0.22	0.00
TOP fore udder	score	0.06	0.05	0.22	0.07	0.06	0.22	0.00
TOP front teat	score	–0.005	–0.009	0.15	0.002	-0.004	0.14	0.00
TOP milking speed	score	0.04	0.04	0.12	0.04	0.04	0.11	0.02
TOP udder support	score	0.02	0.01	0.22	0.02	0.00	0.22	0.02
Total fat	kg	8.98	9.32	12.1	7.80	8.18	12.5	0.00
Total protein	kg	5.09	4.98	12.5	3.06	3.19	12.3	0.00
Total volume	L	–95	–112	436	–171	–190	396	0.00
Herd breed composition								
Foreign Holstein percentage	%	16.5	17.0	11.0	12.6	12.3	10.2	0.00
Holstein Friesian percentage	%	21.4	24.4	12.3	18.6	20.6	12.1	0.00

[1]Total number of records in TAD and OAD herds was 71,321 and 75,213 for all the traits.
[2]TOP = traits other than production
[3]from two-sided t-test of mean between TAD and OAD herds.

(12,826-15,385 L) versus TAD (17,433-19,512 L) herds. The survival rate for the first 6 parities (S12 to S56) in TAD and OAD herds were 79% vs. 81% (P<0.01), 81% vs. 81% (P<0.01), 81% vs. 80% (P<0.01), 79% vs. 77% (P<0.01) and 76% vs. 73% (P<0.01), respectively (Fig. 1). Trait EBV distribution in TAD and OAD herds were very similar (Table 2).

Standardised coefficients for traits of interests were small (Fig. 2). Body Condition Score (BCS) significantly affected TAD survival across the lifetime of an animal, with greater significance in S12 and S23 years. It also affected OAD in S23 and S34 but to a lesser degree. The S12 interaction term was significant, indicating that the effect of OAD was smaller than that of TAD for S12, but in later survivals their effects were similar. Fertility CR42 (calving in the first 6 weeks), Functional Survival and Somatic Cell Count had a highly significant impact on all survivals (S12-S56), with an increasing coefficient value from early to late survivals. In younger parities, within OAD herds Fertility had a smaller effect on survival than in TAD herds. For TOP, Capacity and Milking Speed had a highly significant impact on S12 and S23 in both TAD and OAD herds but in later parities the effects on survival were not consistent. The impact of Front Teat on survival had no consistent trend across parities, and Udder Support showed significant impact on later survivals but not in early survivals. No difference was identified in the TOP effects between OAD and TAD herds. Fat, Protein and Volume EBVs had significant effects on the survival in both TAD and OAD herds across all parities, with the impact of these traits significantly larger in OAD than TAD herds up till the 5th parity.

Discussion

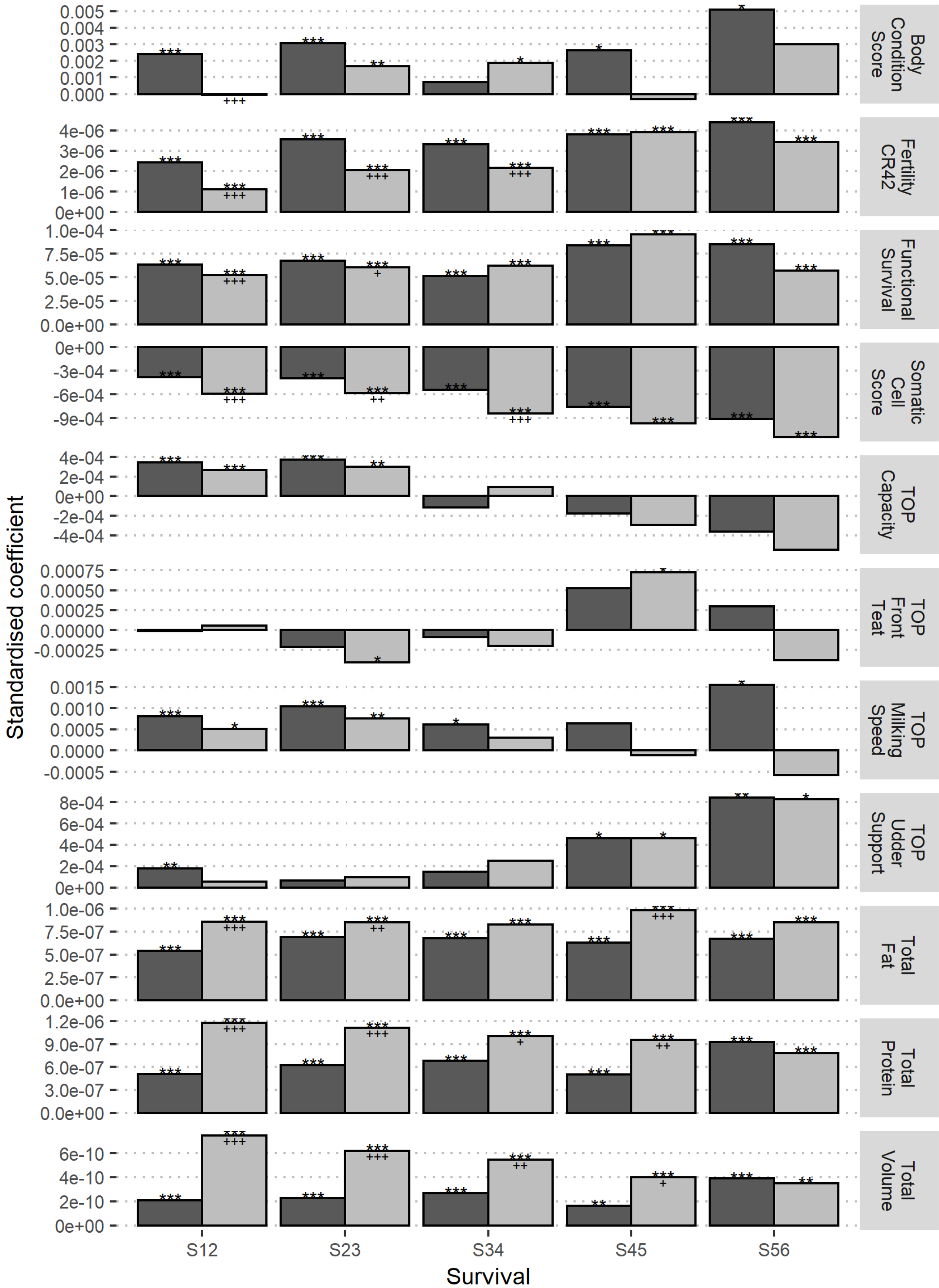
The small scale of standardised coefficients is due to the small variation of underlying distribution of survival (0-1) in the linear regression model. A more suitable logistic regression model was tested but aborted due to the lack of memory space for the analysis. However, since the primary interest of this study was to investigate if there was a significant effect and its relative scale across herd milking frequencies and survival traits rather than the absolute value of the effect, a linear regression model was sufficient given the large number of observations. Furthermore, we didn't show GEBV results in this study because they were very similar to the EBV results that we have reported.

The results of the present study show that the proportion of animals surviving through to the 6th lactation was broadly similar between TAD and OAD (31% v 30%), consistent with previous comparisons that concluded the replacement rate was similar between the two systems (Edwards 2018). However, there were differences in survival across lactations, with a greater proportion of 1st lactation animals surviving in OAD systems, and fewer surviving in later lactations (Fig. 1). This result is also consistent with the previous observation that the average age of cows in OAD herds was significantly less than paired TAD herds (Edwards 2018). The positive effect of OAD on BCS and reproductive performance have been well documented (Clark et al. 2006; Hemming et al. 2018). This is consistent with our results where the survival of younger animals in OAD herds relative to TAD was likely related to reproductive performance, with a significant difference in the relationship between survival and BCS EBV in S12 and Fertility CR42 EBV in S12, S23 and S34. Although, Fertility CR42 still had a significant positive effect on survival in OAD herds. Consequently, we conclude that in OAD systems fertility is an important trait, but that it has less significance in OAD relative to TAD systems.

Our results indicate that production traits (Volume, Fat, and Protein) had a significant positive effect on survival in both TAD and OAD but were significantly more important to survival in OAD herds. Similarly, lower Somatic Cell Score EBV was important for survival in both milking systems, however, it had significantly greater impact in OAD systems in S12, S23, and S34. This is also supported by earlier research that reported a greater proportion of cows removed due to low production and udder related reasons in OAD (Edwards 2018). Logically this should allow for a greater rate of genetic gain for production and milk quality in OAD systems, diminishing any productivity gap between systems, although interestingly in the 5 seasons since adopting OAD it did not appear OAD herds had an increase in the rate of gain of these traits relative to TAD (Edwards 2018). OAD herds are largely dependent on mainstream sires evaluated for their performance in TAD systems, and apart from a limited amount of voluntary culling of cows, will be following the same genetic change trajectory as the rest of the industry. However, overall, our results suggest a greater significance of production and milk quality traits on cow survival in OAD systems relative to TAD.

Our primary hypothesis was that there would be a significant difference in the relationship between TOP traits and survival between OAD and TAD. There were no significant differences in the TOP traits hypothesised to be of greater significance for OAD herds. In general, numerically, these traits were of lesser significance to survival in OAD systems. Udder support became more important in later survivals, which is logical as animals age the udder undergoes fatigue and degradation of the suspensory ligaments, however, it was not more significant within OAD systems relative to TAD. It is not clear what the implications of the significantly lower significance of Functional Survival is in OAD herds for S12 and S23. This is a composite trait containing effects from the EBVs for conformation of the legs, and udder as well as milking speed and body condition score (DairyNZ 2022b). Consequently, this result may be driven by differences in BCS. However, our results do not contain evidence that warrant greater selection pressure on these functional traits in OAD systems relative to TAD to enhance animal survival. One explanation for this result could be that most commercial cows' TOP EBVs are predicted using records

Figure 2 The standardised coefficients[1] and P values[2] of EBV by trait, survival and herd milking frequency (TAD, dark grey; OAD, light grey) from single trait linear regression models and P values[3] of the interaction term from single trait linear regression models with an interaction term.



[1]Standardised coefficient as the product of coefficients and their SE.
[2]The star signs are significance levels of trait effects in either OAD or TAD herds in Equation 1. *: P<0.05, **: P<0.01, ***: P<0.001.
[3]The plus signs are significance levels of the interaction term in the Equation 2, indicating whether the effect is different between OAD and TAD herds. +: P<0.05, ++: P<0.01, +++: P<0.001.

that come from paternal half siblings at 2 years old rather than their own records expressed at the appropriate survival age. So, if these TOP traits are actually more significant for OAD systems, current measurement methods on two-year-old relatives may be unsuitable.

Conclusion

Our results do not contain evidence that warrants greater selection pressure on current estimates of functional traits in OAD systems relative to TAD to enhance animal survival. This could be because current measurement methods for functional traits on two-year-old relatives to generate EBVs may be unsuitable for predicting survival to much later ages in OAD herds. Traits relating to reproductive performance (BCS and fertility) were less significant in OAD systems for younger animals. Consequently, selection pressure could be reduced on these traits in OAD systems, with a greater emphasis placed upon production and milk quality traits, aiding to reduce the difference in productivity between OAD and TAD systems. Furthermore, it raises the question whether replacement rate could be reduced in OAD systems, which may be a more profitable option than removing poor producers.

Acknowledgements

This project was funded by the dairy farmers of New Zealand through DairyNZ Inc, contract BCF6384.

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