New Zealand Journal of Agricultural Research

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tnza20

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To cite this article: Lydia M. Cranston, Brooke A. Ramsay, Jo-Anna A. J. Schoorl, Katie M. Stayton, Alison Greaves, Rachel D. Shanks, Celia J. van Kampen, John F. Cockrem, Ngaio J. Beausoleil, Stephen T. Morris, Nicholas W. Sneddon & Rebecca E. Hickson (03 Sep 2023): Effects of yard weaning and human contact compared to paddock weaning on the liveweight gain and stress reactivity of beef cattle, New Zealand Journal of Agricultural Research, DOI: 10.1080/00288233.2023.2252755

To link to this article: https://doi.org/10.1080/00288233.2023.2252755

Published online: 03 Sep 2023.

NEW ZEALAND JOURNAL OF AGRICULTURAL RESEARCH
https://doi.org/10.1080/00288233.2023.2252755

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RESEARCH ARTICLE

Effects of yard weaning and human contact compared to paddock weaning on the liveweight gain and stress reactivity of beef cattle

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ABSTRACT

In New Zealand beef herds, calves undergo 'paddock weaning' by separating calves and cows into different paddocks. Anecdotal evidence indicates 'yard weaning' whereby calves are yarded and receive regular human contact during weaning may improve long-term stress reactivity and growth rates. Calves were allocated to one of three treatments for seven days post-separation from dams: paddock weaned with minimal human interaction (PN), paddock weaned with daily human interaction (PV), yard weaned with daily human interaction (YV). Calf liveweight, behavioural and physiological measures of stress reactivity and faecal corticosterone concentration were measured. Until day seven, YV calves lost less liveweight than PV or PN calves (0.5 kg vs. 3.5 and 4.8 kg $P < 0.05$). On day seven, PN calves had a 23% greater heart rate compared to YV calves and a greater faecal corticosterone concentration than PV and YV calves (in cohort 2 only) ($P < 0.05$). This indicates, regular non-aversive human contact during weaning may reduce stress associated with the weaning process itself and reduced stress reactivity to subsequent handling and restraint. However, this effect was transient with no consistent longer-term benefits over traditional paddock weaning, in terms of growth or stress reactivity to human handling.

ARTICLE HISTORY
Received 2 February 2023
Accepted 24 August 2023

KEYWORDS
Beef calves; weaning; temperament; flight score; human contact; heart rate; faecal corticosterone

Introduction

Cattle vary widely in their responses to stressful events, and this trait is known as 'stress reactivity' (Grandin 2015). Stress reactivity can be evaluated with physiological variables such as plasma glucocorticoid concentration and heart rate which reflect acute activation of the adrenal and sympathetic stress axes (Sapolsky et al. 2000; Kovács et al.

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2014) as well as through observations of behaviour in response to particular stressors. Several tests, including temperament score and flight speed (Burrow et al. 1988; Grandin 1993), have been developed to reflect the animal's perception of and response to human presence, handling and restraint. The tests observe the escape and avoidance behaviours that cattle display when responding to stressful events, such as handling by humans.

Cattle with lower stress reactivity scores are safer for human handlers, and animals are less likely to injure themselves during handling events (Ceballos et al. 2018). Further, there is evidence that calmer cattle have improved growth rates and carcass characteristics in feedlot systems (Fell et al. 1999; Ferguson et al. 2006). In New Zealand, beef cattle are generally run in extensive pasture-based systems which involve minimal handling by humans (Morris 2018). Kaurivi et al. (2020) interviewed 25 beef breeding cow farmers and found 80% yarded their cows only 3–4 times annually. However, evidence suggests cattle which have experienced positive interactions with humans become less fearful, which in turn, facilitates handling (Schmied et al. 2010; Probst et al. 2012). Consequently, farmers are interested in utilising management practices which might improve the stress reactivity of beef cattle in their farming systems or offer improved cattle performance.

In New Zealand beef cattle systems, calves are born in spring to coincide with peak pasture growth rates and they remain with their dams until they are weaned at approximately six months of age (Morris 2018). Weaning is a stressful time for calves with increased contact and handling by humans as well as separation from their dams and removal of milk from their diet. Calves are normally abruptly weaned by removing the dams and placing the calves in a separate paddock with free access to pasture, a process referred to as 'paddock weaning'. This weaning process commonly results in calves attempting to establish contact with their dams by being more vocal, running along fence lines and spending less time grazing (Price et al. 2003). Not only do calves experience stress but they often have negative or slow growth rates in the period following paddock weaning (Haley et al. 2005).

Conversely, in Australian beef cattle systems it is more common to use 'yard weaning' whereby calves are removed from dams and placed in an enclosed yard with *ad libitum* access to feed and regular human contact (Colditz et al. 2006). It has been suggested that yard weaning may reduce the stress reactivity of calves associated with weaning compared to the more typical practice of paddock weaning. Further it allows for more frequent calf-human interaction and may help to improve the stress reactivity of cattle in later life (Beef + Lamb New Zealand 2019; Probst et al. 2012).

In addition to improving future reactivity to common stressors, yard weaning may reduce the stress experienced during the process itself. The animal's perception of its longer-term or integrated living conditions can be evaluated using more cumulative measures such as faecal cortisol metabolites (Möstl et al. 2002; Little et al. 2015; Ebinghaus et al. 2020; Vogt et al. 2023) and growth rates. Yard-weaned calves have been observed to have greater growth rates than pasture-weaned calves in the first month following weaning as well as after a 90-day finishing period in a feedlot in Australia (Fell et al. 1998).

This improved productivity, combined with improved health indicators in yard-weaned calves (Fell et al. 1998) has led to yard weaning being widely adopted in farming systems in Australia and accepted as 'best practice' (Colditz et al. 2006). On-farm studies in New Zealand have shown mixed results in terms of the impact of yard weaning on liveweight gain, but the farmers involved subjectively reported improved temperament of the calves (Beef + Lamb New Zealand 2019). However, these studies only compared yard weaning with human interaction to paddock weaning without human interaction and therefore it could not be determined from these studies whether it was enclosure in the yards or regular human interaction that contributed to the reported improvements in temperament.

The main aim of this study was to determine whether the growth rate or stress reactivity of beef calves could be improved by yard weaning with regular human interaction, or by paddock weaning with regular human interaction compared to conventional practice (paddock weaning with minimal human contact). It was hypothesised that, regardless of location, regular, non-aversive human contact during weaning would reduce behavioural and physiological reactivity to subsequent human contact and handling. We also hypothesised that the stress associated with the process of yard-weaning would be lower than that associated with conventional paddock-weaning, reflected in lower faecal corticosterone concentrations and higher liveweight gains during and after weaning.

Materials and methods

Animals

This research was conducted at Tuapaka Farm, in Manawatu, New Zealand (40°21′S, 175°45′E), with approval from the Massey University Animal Ethics Committee, in autumn 2016 (cohort 1) and 2017 (cohort 2). All calves were kept with their dams, under paddock grazing until weaning. Cohort 1 comprised 47 crossbred calves (21 heifers, 26 steers), whose sires were Charolais, and whose dams were Angus ($n = 19$), Angus × Friesian ($n = 10$), Angus × Jersey ($n = 13$) and Angus × (Friesian × Jersey) ($n = 5$) cows. Cohort 2 comprised 42 straight-bred Angus calves (25 heifers, 17 steers). The dams of both cohorts were born and reared by a cow, i.e. no dams were hand-reared by humans. Cohort 1 calves were handled twice within 48 h of birth (for ear tagging and collection of a blood sample) and in the yards four times prior to weaning for weighing, castration and vaccination. In contrast, cohort 2 calves were handled once in the paddock for ear tagging within 24 h of birth and once through the yards (for castration and vaccination) prior to weaning.

Table 1. Experimental design of the study.

Treatments	Cohort 1 (2016) Crossbred calves*	Cohort 2 (2017) Angus Calves
Paddock weaned with minimal additional human interaction (PN)	Group 1: $n = 8$	Group 1: $n = 7$
	Group 2: $n = 8$	Group 2: $n = 7$
Paddock weaned with daily human interaction (PV)	Group 1: $n = 8$	Group 1: $n = 7$
	Group 2: $n = 7$	Group 2: $n = 7$
Yard weaned with daily human interaction (YV)	Group 1: $n = 8$	Group 1: $n = 7$
	Group 2: $n = 8$	Group 2: $n = 7$

*Calves were sired by a Charolais bull and dams were Angus ($n = 19$), Angus × Friesian ($n = 10$), Angus × Jersey ($n = 13$) and Angus × (Friesian × Jersey) ($n = 5$) cows.

Study design

Calves within each cohort were allocated to one of three treatments in a 3 × 2 factorial design (three treatments × two cohorts; Table 1). Each treatment had two groups within each cohort that were contained in separate paddocks or yards (Table 1). A fourth treatment (yard weaned with minimal additional human interaction) was included in the study design but was excluded from analysis as some of the calves escaped from their enclosure. Calves were assigned to a group at weaning (Day 0 (D0)); at an average age of 198 (SD 12) days and a live weight of 276 (SD 35.2) kg for cohort 1 and an average age of 208 (SD 13) days and live weight of 208 (SD 26.0) kg for cohort 2. The groups were balanced as best as possible for sex, and for live weight and temperament score on D0. For cohort 1, groups were also balanced for breed of dam. The difference in live weight between cohorts was due to the different genetics of the calves and dams involved, with the Charolais-sired calves of better growth potential and their crossbred dams of better milking potential than the Angus calves and their Angus dams.

At weaning on D0, dams were moved several km away to a paddock out of sight or sound of all calves. Paddock-weaned calves were confined to a flat paddock that ranged between 2.36 and 4.98 hectares and contained perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) pasture. Pre-grazing pasture mass ranged between 1800 and 2500 kg DM/ha and was sufficient to allow *ad libitum* intake until D7 (Morris 2007). The paddocks selected had not recently been grazed by the cattle. Yard-weaned calves were confined to a pen (12 × 12 m) lined with wood chip bedding (minimum area of 18.0 m^2 per calf). Each pen contained one feeder which offered *ad libitum* pasture baleage and allowed all calves to access the feeder simultaneously. A new bale of baleage was added to each feeder on D4. Fresh water was available continually to all calves.

New Zealand beef cattle farms, including the one used in this experiment, are subdivided into many paddocks of varying size using permanent fencing (individual paddocks were up to 14 ha in area on the farm in this experiment), and cows and calves are frequently moved to new paddocks. Therefore, the paddocks that calves were placed in after weaning were familiar concepts, even though the specific paddocks were novel to the calves. Similarly, the pens were a familiar space for the calves in cohort 1 which had been yarded frequently before weaning, but relatively unfamiliar for the calves in cohort 2. Key differences between the yards and the paddocks included the area (approximately 150 m^2 versus 2.36–4.98 ha), feed available (baleage versus pasture), exposure to humans (the yards were located near a farm access point so calves were exposed to the daily activities of the farm staff, whereas the paddocks were away from any other activities), and the ability of calves to move away from humans (calves in yards could only move across the pen, < 20 m, whereas calves in paddocks could maintain their preferred flight distance).

Daily human interaction from D1 to D6 consisted of an 18-min visit from the same person, who spoke calmly and moved towards each calf until it moved away. The person presented to the calves wearing different clothing (overalls, lab coat, neon vest, hat) and carrying different accessories (stick, plastic bag) each day to habituate the calves to people in general, rather than to a specific individual. Paddock-weaned groups that received minimal human interaction (PN) were separated from those that received daily human interaction (PV) by a shelterbelt that blocked sight of the human.

On D7, all calves were re-drafted on the basis of sex, and heifers and steers were grazed separately (total of two groups) until D42. During this period, calves were managed according to commercial practice, grazing perennial ryegrass and white clover pasture and brought in for one yarding event for anthelmintic drenching.

Animal measurements

Heart rate, live weight, temperament score and step count of calves were measured on D0, D7 and D42, using the procedure outlined in Ramsay et al. (2017). Calves from all treatments (within cohort) were mixed together to allow for blind measurement. Heart rate was measured for 15 s via auscultation while calves were restrained in a race. Auscultation was conducted within 2 min of calves entering the race. The calves then individually entered a weigh crate (2.1 m^2 with a steel floor, closed sides and a barred front gate) where they were weighed, temperament scored and their number of steps taken were counted. Within cohort, the same trained assessor (blinded to treatment) made all temperament score assessments. The assessors were trained prior to the study using an unrelated mob of calves but no evaluation of intro-assessor reliability was made. Forelimb steps were counted by a second individual for the 30 s that each calf was in the crate (at the same time as temperament scoring was carried out). The temperament score was assessed over the first 30 s in the crate, based on a five-point scale of Ramsay et al. (2017). A score of 1 was calm, no movement, head mostly still; 2 was slightly restless, looking around frequently, moving feet; 3 was frequently moving feet but not moving back and forth, excessive head movement; 4 was agitated, moving back and forth; and 5 was very agitated, continuous vigorous movement, snorting. Vocalisation and movement of the feet, head or tail were interpreted as signs of agitation (Grandin 2015).

On D7 and D42 the time to exit (flight score) of calves was also measured. Calves were held individually in a 1.5 m^2 pen for 20 s before being released into a holding paddock. The time to exit was recorded by one individual using a stopwatch as the time taken for a calf to travel 5 m from the exit gate (adapted from Burrow et al. 1988).

Samples of fresh faeces were collected on D0, D2, D7 and D42. Each sample used for analysis comprised three 20 g subsamples, each from a separate faecal mass (Ramsay et al. 2017). Baseline samples ($n = 10$) were collected on D0 from the paddock where all calves had grazed with their dams, following removal of the cattle (i.e. prior to assigning calves to treatment groups). Samples were randomly collected from the ground as calves were observed to defaecate on their walk from the paddock to the yards. On D2, D7 and D42 samples were collected by walking around the paddock or yards with the calves, and as calves defaecated, calf number was identified, and the sample was linked to a given treatment. On D2 and D7, two samples were collected from each group (four samples per treatment, samples from 50% of animals in a treatment), between 2 and 4h after calves were released from yarding. On D42, faecal samples were again collected between 2 and 4 h after calves were released from yarding. For cohort 1, 26 samples were collected (PN, $n = 9$; PV, $n = 11$; YV, $n = 6$), while for cohort 2, time limitations meant 6 samples were collected (2 samples per treatment). Whilst this limited the sample size it was deemed to provide a representative sample of the group. Corticosterone concentration of the samples was analysed using radioimmunoassay according to the method of Little et al. (2015), after the samples had been frozen at −20°C for up to 50 days.

Herbage measurements

Hand-plucked grab samples were collected from each of the perennial ryegrass and white clover pasture-fed group (PN and PV) on D0 and from the pasture baleage-fed groups (YV) on D0 and D4 (one sample per bale offered; Frame 1993). The samples from D0 and D4 were combined so that each group had a single pooled representative sample. The samples were freeze-dried and ground to pass a 1 mm sieve. The freeze-dried samples were analysed using wet chemistry for crude protein (CP; 'Dumas procedure', AOAC method 968.06 using a Leco total combustion method) and digestible organic matter digestibility (DOMD; Roughan and Holland 1977). Metabolisable energy content was calculated as DOMD × 0.163, according to Roughan and Holland (1977). The pasture baleage had a mean metabolisable energy (ME) and crude protein (CP) content of 9.8 MJ ME/kg DM and 14.4% CP in 2016 and 9.0 MJ ME/kg DM and 12.6% CP in 2017. The perennial ryegrass and white clover pasture had a mean ME and CP content of 10.3 MJ ME/kg DM and 24.2% CP in 2016 and 9.6 MJ ME/kg DM and 19.1% CP in 2017.

Statistical analysis

All statistical analyses were performed using SAS (Statistical Analysis System, version 9.4; SAS Institute Inc., Cary, NC, US), with calf as the experimental unit. Separate analyses were carried out for each day of measurement.

Live weight, heart rate, step count (while held in weigh crate), exit time and change in these variables were analysed using general linear models that considered the fixed class effects of sex of calf, treatment (PN, PV, YV) and cohort, and the two-way interactions between these effects. For temperament score, the analysis was conducted using the genmod procedure with a Poisson distribution; the model included the fixed class effects of sex of calf, treatment (PN, PV, YV) and cohort. Exit time was analysed using the same approach after normalising using a natural logarithm transformation. The mean and standard error of the mean were calculated for the baseline faecal corticosterone concentration (prior to treatments being imposed). Faecal corticosterone concentration (during the experimental period) was analysed using a mixed model that included the fixed effects of treatment (PN, PV, YV) and cohort. Group (within cohort and treatment) was considered as a random effect in all models but was removed as it was not significant ($P > 0.1$) for any trait. Similarly, the order in which the calves underwent measurement had no significant effect on any parameter so was excluded from the final models. Interactions were retained in models only where they were significant for at least one measurement of that type – this led to the removal of all three-way interactions. Additionally, all models were also analysed within cohort, but the results were found to not be significantly different to those obtained using the analysis described above.

The final models were:

$$y_{ijkm} = \mu + c_j + w_k + s_m + c_j \times s_m + e_i \quad (1)$$

for live weight and change in live weight;

$$y_{ijkm} = \mu + c_j + w_k + s_m + e_i \quad (2)$$

for heart rate, step count and change in these variables; and

$$y_{ijkm} = \mu + c_j + w_k + s_m + c_j \times s_m + c_j \times w_k + e_i \quad (3)$$

for log-transformed exit time; where y_{ijkm} is the observation on the i^{th} calf in the j^{th} cohort in the k^{th} weaning treatment of the m^{th} sex, c_j is the fixed effect of the j^{th} cohort, w_k is the fixed effect of the k^{th} weaning treatment, s_m is the fixed effect of the m^{th} sex, and e_i is the residual error.

Results

Live weight

There was no effect ($P > 0.05$) of weaning treatment on the live weight of calves at any measurement date (Table 2). Between D0 and D7, YV calves lost less ($P < 0.05$) live weight than PV and PN calves, which did not differ ($P > 0.05$) from one another. In contrast, between D7 and D42, YV calves gained less ($P < 0.05$) live weight than PV and PN calves, which did not differ ($P > 0.05$) from one another. Between D0 and D42, there was an interaction ($P < 0.05$) between cohort and weaning treatment. The weaning treatment groups within cohort 1 did not differ ($P > 0.05$) in their change in live weight but gained

Table 2. Live weight and liveweight change of 89 calves from 2 cohorts that were paddock weaned with minimal contact (PN), paddock weaned with human interaction (PV) or yard weaned with human interaction (YV) on day of weaning (D0), seven days after weaning (D7) and 42 days after weaning (D42). Values are LSM ± SEM.

	Live weight (kg)			Liveweight change (kg)		
	D0	D7	D42	D0 to D7	D7 to D42	D0 to D42
Cohort						
1	$275.2^b \pm 4.3$	$268.5^b \pm 4.2$	$285.5^b \pm 4.4$	$-6.7^a \pm 0.8$	$17.0^a \pm 1.38$	$10.3^a \pm 1.4$
2	$209.6^a \pm 4.6$	$210.4^a \pm 4.5$	$245.9^a \pm 4.7$	$0.8^b \pm 0.9$	$35.5^b \pm 1.48$	$36.6^b \pm 1.5$
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Treatment						
PN	243.5 ± 5.5	238.6 ± 5.3	267.7 ± 5.6	$-4.8^a \pm 1.1$	$29.1^b \pm 1.76$	24.7 ± 1.7
PV	242.4 ± 5.4	238.9 ± 5.3	266.7 ± 5.6	$-3.5^a \pm 1.1$	$27.9^b \pm 1.75$	24.4 ± 1.8
YV	241.4 ± 5.4	241.0 ± 5.2	262.7 ± 5.5	$-0.5^b \pm 1.0$	$21.7^a \pm 1.73$	21.3 ± 1.7
P value	0.964	0.941	0.793	0.012	0.007	0.302
Cohort by treatment						
1-PN	276.5 ± 7.4	270.0 ± 7.2	288.0 ± 7.6	−8.6 ± 1.4	20.0 ± 2.4	$11.8^a \pm 2.4$
1-PV	275.5 ± 7.6	267.6 ± 7.4	283.5 ± 7.8	−7.9 ± 1.5	15.9 ± 2.4	$7.8^a \pm 2.5$
1-YV	273.6 ± 7.3	270.0 ± 7.2	284.9 ± 7.6	−3.6 ± 1.4	14.9 ± 2.3	$11.5^a \pm 2.4$
2-PN	209.7 ± 8.1	208.7 ± 7.9	246.7 ± 8.3	−1.07 ± 1.6	38.0 ± 2.6	$37.7^{bc} \pm 2.6$
2-PV	209.2 ± 7.8	210.1 ± 7.6	250.1 ± 8.1	0.9 ± 1.5	40.0 ± 2.5	$41.0^c \pm 2.5$
2-YV	205.5 ± 8.2	208.5 ± 8.0	236.5 ± 8.4	2.9 ± 1.6	28.0 ± 2.6	$31.0^b \pm 2.6$
P value	0.994	0.965	0.640	0.735	0.086	0.028

[a,b,c]Means with different superscripts within columns and effects are significantly different ($P < 0.05$).

less ($P < 0.05$) live weight than all cohort 2 weaning treatment groups. In cohort 2, PV calves gained more ($P < 0.05$) live weight than YV calves.

Heart rate

Cohort 2 calves had faster ($P < 0.05$) heart rates than cohort 1 on D0, but had similar ($P > 0.05$) heart rates on D7 and D42 (Table 3). On D0, there was no difference ($P > 0.05$) in the heart rates of calves in the different treatment groups, however, on D7, PN calves had 23% faster ($P < 0.05$) heart rates than YV calves, but neither differed ($P > 0.05$) from PV calves. Between D0 and D7, the heart rates of PN calves increased ($P < 0.05$), whereas that of YV calves decreased ($P < 0.05$). On D42, PN calves had 17% faster ($P < 0.05$) heart rates than PV calves, but neither differed ($P > 0.05$) from YV calves.

Temperament score and number of steps

There was no effect ($P > 0.05$) of cohort, weaning treatment or sex of calf on temperament score or the change in temperament score following weaning (Table 4). Cohort 2 calves took a greater ($P < 0.05$) number of steps than cohort 1 calves on all measurement dates. Weaning treatment groups did not differ ($P > 0.05$) in the number of steps taken on D0 or D7. However, on D42, there was an interaction ($P < 0.05$) between cohort and weaning treatment, such that in cohort 1, PN and YV calves took a similar ($P > 0.05$) number of steps (13.9 ± 2.74 and 13.5 ± 2.73, respectively) but fewer ($P < 0.05$) steps than the PV calves (22.9 ± 2.81). In contrast in cohort 2, PN calves took fewer ($P < 0.05$) steps than YV calves (18.0 ± 2.95 and 29.1 ± 2.92, respectively), with PV calves (24.3 ± 2.91) not differing ($P > 0.05$) from either weaning treatment group.

Exit time

Cohort 2 calves had faster ($P < 0.05$) time to exit compared with cohort 1 on both D7 and D42 (Table 5). There was no effect ($P > 0.05$) of weaning treatment on time to exit on either measurement date.

Table 3. Heart rate and change in heart rate of 89 calves from 2 cohorts that were paddock weaned with minimal contact (PN), paddock weaned with human interaction (PV) or yard weaned with human interaction (YV) on day of weaning (D0), seven days after weaning (D7) and 42 days after weaning (D42). Values are LSM ± SEM.

	Heart rate (beats/min)			Change in heart rate (beats/min)		
	D0	D7	D42	D0 to D7	D7 to D42	D0 to D42
Cohort						
1	92.4^{a} ± 3.4	100.4 ± 4.2	97.3 ± 3.5	8.0^{b} ± 4.5	−3.2 ± 5.1	4.9^{b} ± 4.9
2	115.6^{b} ± 3.6	103.2 ± 4.4	99.1 ± 3.8	-11.5^{a} ± 4.9	−4.1 ± 5.4	-16.5^{a} ± 5.2
P value	<0.001	0.655	0.723	0.004	0.905	0.004
Treatment						
PN	101.9 ± 4.3	111.8^{b} ± 5.2	107.3^{b} ± 4.4	9.9^{b} ± 5.6	−4.48 ± 6.4	5.4 ± 6.2
PV	103.6 ± 4.4	103.0^{ab} ± 5.3	91.1^{a} ± 4.5	-0.6^{ab} ± 5.7	−11.9 ± 6.5	−12.5 ± 6.3
YV	106.5 ± 4.3	90.6^{a} ± 5.2	96.2^{ab} ± 4.4	-14.6^{a} ± 5.7	5.5 ± 6.4	−10.3 ± 6.2
P value	0.756	0.019	0.035	0.012	0.162	0.088

[a,b]Means with different superscripts within columns and effects are significantly different ($P < 0.05$).

Table 4. Temperament score and number of steps (while held in weigh crate) of 89 calves from 2 cohorts that were paddock weaned with minimal contact (PN), paddock weaned with human interaction (PV) or yard weaned with human interaction (YV) on day of weaning (D0), seven days after weaning (D7) and 42 days after weaning (D42). Values are LSM ± SEM.

	Temperament Score (1–5 scale[1])			Number of steps		
	D0	D7	D42	D0	D7	D42
Cohort						
1	3.1 ± 0.3	2.5 ± 0.2	2.6 ± 0.2	20.0^a ± 1.5	10.7^a ± 1.5	16.8^a ± 1.6
2	2.9 ± 0.3	2.5 ± 0.2	3.0 ± 0.3	24.9^b ± 1.6	17.1^b ± 1.6	23.8^b ± 1.7
P value	0.586	0.965	0.282	0.028	0.006	0.003
Treatment						
PN	2.9 ± 0.3	3.0 ± 0.3	2.7 ± 0.3	20.6 ± 1.9	16.3 ± 1.9	16.0^a ± 2.0
PV	3.2 ± 0.3	2.6 ± 0.3	2.9 ± 0.3	24.0 ± 1.9	13.1 ± 2.0	23.6^b ± 2.0
YV	2.9 ± 0.3	2.2 ± 0.3	2.8 ± 0.3	22.8 ± 1.9	12.4 ± 1.9	21.3^b ± 2.0
P value	0.790	0.145	0.899	0.436	0.317	0.026

[1]Temperament score on a 1–5 scale where 1 = calm and 5 = very agitated.
[a,b]Means with different superscripts within column and effect are significantly different ($P < 0.05$).

Faecal corticosterone

The mean pre-weaning faecal corticosterone concentration was 21.1 ± 6.44 ng/ml in cohort 1 and 33.4 ± 12.47 ng/ml in cohort 2. Cohort 2 calves had greater ($P < 0.05$) faecal corticosterone concentrations at all measurement dates compared with cohort 1 (Table 6). On D2, PN calves had greater ($P < 0.05$) faecal corticosterone concentrations than PV calves, but YV calves did not differ ($P > 0.05$) from either treatment group. On D7, there was an interaction ($P < 0.05$) between cohort and weaning treatment, such that, PN calves born in 2017 had a greater ($P < 0.05$) faecal corticosterone concentration than the other two weaning treatment groups, which did not differ ($P > 0.05$) from one another. On D42, there was no difference ($P > 0.05$) in the faecal corticosterone concentrations among the weaning treatment groups.

Discussion

Despite the yard-weaned calves losing less live weight than paddock-weaned calves in the first seven days after weaning, there was no liveweight advantage of yard weaning calves, when measured six weeks later. The feed on offer to the yard-weaned calves was not

Table 5. Time to exit (seconds) of 89 calves from 2 cohorts that were paddock weaned with minimal contact (PN), paddock weaned with human interaction (PV) or yard weaned with human interaction (YV) on day of weaning (D0), seven days after weaning (D7) and 42 days after weaning (D42). Values are LSM ± SEM with back-transformed mean in parenthesis.

	D7	D42
Cohort		
1	1.4^b ± 0.1 (4.19)	1.1^b ± 0.1 (3.09)
2	1.2^a ± 0.1 (3.17)	0.7^a ± 0.1 (1.95)
P value	0.025	<0.001
Treatment		
PN	1.2 ± 0.1 (3.24)	0.9 ± 0.1 (2.42)
PV	1.4 ± 0.1 (3.93)	0.9 ± 0.1 (2.48)
YV	1.3 ± 0.1 (3.81)	0.9 ± 0.1 (2.46)
P value	0.369	0.954

[a,b]Means with different superscripts within column and effect are significantly different ($P < 0.05$).

Table 6. Faecal corticosterone concentration (ng/ml) of calves from 2 cohorts that were paddock weaned with minimal contact (PN), paddock weaned with human interaction (PV) or yard weaned with human interaction (YV) 2 days after weaning (D2), 7 days after weaning (D7) and 42 days after weaning (D42).

	D2	D7	D42
Cohort			
1	$22.2^{a} \pm 2.3$	$22.7^{a} \pm 2.8$	$22.2^{a} \pm 1.4$
2	$39.0^{b} \pm 2.3$	$39.2^{b} \pm 2.8$	$42.6^{b} \pm 2.8$
P value	<0.001	<0.001	<0.001
Treatment			
PN	$37.6^{b} \pm 2.8$	$43.1^{b} \pm 3.4$	33.4 ± 2.3
PV	$24.8^{a} \pm 2.8$	$27.9^{a} \pm 3.4$	31.3 ± 2.2
YV	$29.4^{ab} \pm 2.8$	$21.9^{a} \pm 3.4$	32.5 ± 2.6
P value	0.015	0.001	0.761
Cohort by Treatment			
1-PN	29.4 ± 4.2	$22.5^{a} \pm 4.9$	22.4 ± 2.3
1-PV	17.6 ± 4.2	$23.0^{a} \pm 4.9$	21.5 ± 2.1
1-YV	19.7 ± 4.2	$22.7^{a} \pm 4.9$	22.9 ± 2.9
2-PN	45.7 ± 4.2	$63.7^{b} \pm 4.9$	47.2 ± 5.0
2-PV	32.1 ± 4.2	$32.9^{a} \pm 4.9$	39.7 ± 5.0
2-YV	39.1 ± 4.2	$21.1^{a} \pm 4.9$	41.0 ± 5.0
P value	0.845	0.001	0.621

Values are LSM ± SEM.
[a,b]Means with different superscripts within column and effect are significantly different ($P < 0.05$).

higher quality, in terms of crude protein or metabolisable energy, compared with the pasture on offer to the paddock-weaned calves. Therefore, nutritive value was not likely to be the driver of this liveweight difference – in fact, the protein percentage of the baleage fed to yard-weaned calves was low for growing calves (Brookes and Nicol 2007), and this may have limited their potential growth during this period.

Instead, it is probable that the yard-weaned calves expended less energy during the immediate weaning period. Price et al. (2003) observed that calves spent more time walking and less time eating and resting for several days after weaning. Nickles et al. (2020) reported that paddock-weaned calves walked 8.98 km on the day of weaning and walking distances did not return to pre-weaning daily walking distances for a further 2–3 days. Given that calves were confined during yard weaning, their physical activity may have been limited relative to the paddock-weaned calves.

Nevertheless, the liveweight advantage did not persist at six weeks post weaning, and, therefore, was of little practical benefit to a New Zealand pasture-based farmer. In Australia, Fell et al. (1998) observed yard-weaned calves had a liveweight gain advantage relative to pasture-weaned calves in the first 30 days in a feedlot finishing system, when they were introduced to a feedlot 6–9 months after weaning, but New Zealand cattle are finished on pasture, so a growth benefit is unlikely to be realised later for calves in New Zealand.

Calves in cohort 1 had a greater weaning check than calves in cohort 2, which may have been at least partly due to cohort 1 calves having potentially greater milk consumption prior to weaning from their crossbred dams (Roca Fraga et al. 2016), and so experiencing a greater change in diet from withdrawal of milk at weaning. This may also contribute to the interactive effect of cohort and treatment, whereby the visited paddock-weaned calves in cohort 2 had greater liveweight gain in the 42 days after weaning than the yard-weaned calves because paddock-weaned calves in cohort 2 would likely have experienced the least change in diet from weaning.

Farmers who carried out on-farm studies in New Zealand commented that 'yard weaned calves were noticeably quieter than paddock weaned calves over the year following weaning' (Beef + Lamb New Zealand 2019). This benefit is most appealing to extensive hill-country farms where cattle are rarely handled and the temperament of some cattle on these properties is 'wild'. In the present study, the cohort 1 calves, prior to weaning had all been handled numerous times and were observed to be calmer than cohort 2 calves prior to the weaning process.

Anecdotal evidence suggests that yard weaning is most beneficial for cattle with 'nervous or wild' temperaments as opposed to those with calm temperaments. Thus, the dams and calves in cohort 2 were selected to test flightier cattle. The greater effect was evidenced by faster heart rates in response to restraint, higher step counts while held in the weigh crate before the start of weaning, faster time to exit and higher faecal corticosterone concentrations of the Angus calves in cohort 2.

Heart rate is elevated during periods of acute stress (Ferguson et al. 2006). The smaller heart rate response of YV calves to handling and restraint compared with PN calves at D7 might indicate that yard weaning habituated calves to aspects of the testing stressor (human presence and closer confinement) and so they found subsequent handling and restraint less stressful. However, this difference might also reflect that the paddock-weaned calves had been moved around 900 m to the yards for measurement, whereas the yard-weaned calves had moved only from an adjacent pen. The difference in heart rate between the PV and PN calves at D42 is likely to reflect that the PV calves were less stressed by yarding and proximity of a human due to their previous experience of humans during weaning.

The greater faecal corticosterone concentrations in PN calves during (D2) and following the weaning period (D7; cohort 2 only), compared with those which received regular human contact, suggests that stress of calves could be reduced during weaning if calves receive regular non-aversive human contact, however, further research is required to confirm this. Importantly, the timing of faecal sampling meant that corticosterone levels reflected the calves' perception of the weaning process per se, rather than of acute handling and restraint for testing stress reactivity. Thus, the process of paddock- or yard-weaning with regular, non-aversive human contact appeared to be less stressful for calves than conventional paddock-weaning with minimal human contact. As weaning is a key stressor in the lives of farmed mammals, this finding of a short-term effect still represents a management opportunity to improve the overall welfare of beef cattle.

Overall, however, there was no longer-term improvement in the stress reactivity traits of the yard weaned calves throughout the study. Other studies involving *Bos indicus* cattle have also found that short-term training (additional handling) at weaning was not sufficient to improve flight times (stress reactivity) (Burrow and Dillon 1997; Fell et al. 1999).

Change in diet, change in environment and separation from their dam are all potential sources of stress at weaning. All calves in this experiment experienced similar separation from their dams, but the extent to which the diet and environment changed differed among treatments and cohorts. This study design did not allow for the identification of which stressors were most important or which may have contributed to the differences observed. The experiment was designed to compare systems of weaning, and the conditions imposed were typical of the different systems. The re-grouping of calves from different treatments following weaning was necessary to allow the comparison of growth rate, however, it may have influenced the expression of temperament measurements, if calves were affected by the presence of other calm or excitable animals. Similarly, the group sizes used here were smaller than typical of hill country beef herds, and this may have impacted on calf stress levels.

Conclusion

The findings of this study indicate that under New Zealand pastoral grazing systems, the stress reactivity of beef calves to human handling was reduced by regular non-aversive human contact during weaning. In addition, stress associated with the weaning process itself seemed to be reduced by regular human contact, providing a short-term improvement in animal welfare. However, when measured six weeks post-weaning, there was only minor evidence of a longer-term benefit in stress reactivity and no advantage, in terms of liveweight, of yard weaning or more regular human contact during the weaning period compared to conventional paddock weaning.

Acknowledgements

This research was funded by Beef + Lamb New Zealand and Massey University. The authors acknowledge the technical assistance of D. L. Burnham.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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