

Performance and Behavioural Effects of Separating Dairy Cows and Their Calves at Birth

A Knowledge Summary by

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PICO question

In Dairy Cows and Calves separated at birth vs. suckled with the mother, are there any behavioural and performance effects on both cow and/or calf?

Clinical bottom line

Calves allowed to suckle from their mothers show stronger behavioural bonds at weaning and appear to gain more weight (at weaning) than separated and automatically fed calves. However, due to the milk yield loss and subsequent favourable weight gains after weaning from ad lib suckling, automatically fed groups make separation at birth a preferable economic decision.

Clinical Scenario

Separation of dairy calves within minutes to hours after birth is a popular concern raised with the public around intensive farming debates (Hotzel et al., 2017). Hotzel's survey suggests that even when the public are given additional information on separation, this is not likely to increase public support. Although it has been well-established that risk of Johnes' disease (*Mycobacterium paratuberculosis*) transfer is reduced with quick separation (Windsor & Whittington, 2010), there have been other publications indicating that the mother-calf bond may have beneficial effects on behaviour and learning capabilities of calves (Costa et al., 2016; Valnickova et al., 2015). It would be interesting to get an updated overview of behavioural effects, effects on production gains or losses and weight gain on both calves and mothers so that the general practitioner can give more informed advice to both the public and their farm clients.

The evidence

As this review combines two outcomes, that of behavioural effects of separation at birth and of performance characteristics of calves and mothers, I will address these two aspects separately, below:

Behaviour:

Many of the articles published on separation at birth address the aspect of how this can affect the mother-calf bond and focus on the interactions between both mother and calf and calf to calf interaction. Most of the evidence comes from observational research, either by videotaping, direct observation or vocalisation recording. Behaviours that were measured tended to be specific to those observed by a previous literature review that attempts to describe normal behaviour; seeking peers or the mother, interactions at play or calling (von Keyserlingk & Weary, 2007). Therefore, head movements, licking, ear "flicks" or movements towards audio stimuli and locomotor play are often parameters chosen to be measured. Of the behaviour reviewed in this paper, the following results appear to be reliable or consistent:

- There appears to be no effect on head movement, play, ear flicking or licking related to sex of the calf (Stehulova et al., 2017)
- Vocalisation of the mother is greater when there is a solid wall, but audio contact, between calf and mother at weaning/separation. Vocalisation behaviour increases with further contact with the mother from birth (Stehulova et al., 2017; Johnsen et al., 2015)
- Vocalisation of calves to mothers is higher when there is a solid wall, but audio contact, between calf and mother at weaning/separation. This also increases with further contact with the mother from

birth (Stehulova et al., 2017; Johnsen et al., 2015)

- Vocalisation behaviour is specific to the mother's own calf (Marchant-Forde, 2002)
- Vocalisation of calf to mother at separation increases with more time with the mother (Weary & Chua, 2000)
- When calves are separated from their mothers for short periods of time, they appear to lick and move their heads towards their mothers on returning. This behaviour increases with increasing length of contact time (in days) between mother and calf. The reverse is true of mother to calf in licking/head movements (Jensen, 2011)
- Individually housed calves have less social interactive skills and have lower cognitive test results when learning than socially housed calves (Costa et al., 2016)

From this, it is suggested that the calf to mother bond increases with increasing time to weaning and mothers/calves bond to their specific parents/offspring. These bonding behaviours however, appear to be present even after 6 hours from birth (Stehulova et al., 2017), so separation from this time onwards would appear to have a behavioural effect on the animals concerned.

Performance:

In terms of performance characteristics, articles tended to measure body weights at specific times to and after weaning, daily growth rates to and after weaning and milk yield of mothers. Some papers also measured feed intake of calves but also tried to relate this to growth in the same observations. In most experiments, separated calves are fed whole milk from the same herd in an attempt to equate composition but in those where replacer is used (Lee et al., 2009) composition and formulation become important. Daily intake of fed milk/replacer is also a factor influencing growth rates and this is addressed where possible however, intake of suckling calves is impossible to measure directly and the composition is very difficult to determine. Cows that are milked in the parlour but who are still suckling may have very different fat/protein components that their calves are given access to. This makes direct comparisons of growth rates in suckled and separated calves less easy to determine.

Weight gain:

- Calves appear to gain more weight when suckling with their mothers, increasing with time up to 2 weeks after birth (Valnickova et al., 2015)
- Calves fed whole milk vs. milk replacer with similar ingredients have better growth rates (Lee et al., 2009)
- Calves staying with their mothers for up to 6 weeks, gained weight at 3 times the rate of separated calves up to 6 weeks (Roth et al., 2009)
- Calves on automatic feeders gain more weight than suckled calves after weaning (0.4 kg/d) (Roth et al., 2009)
- Calves on automatic feeders eat 16–19 kg more concentrates (total) until weaning than suckled calves (Roth et al., 2009)
- Calves kept with their mothers gain 25–28 kg more than automatic fed calves to weaning (Roth et al., 2009)
- The longer calves are with their mothers, the more weight they gain in comparison to weaning (Kisak et al., 2011)
- There is no evidence of any difference between group or individually housed calves or separated/suckled calves on disease rates (Costa et al., 2016; Grondahl et al., 2007; Kisak et al., 2011; Lee et al., 2009)

Milk Yield of mothers

- Mothers with calves give up to 14 kg less milk per day up to weaning, having effects into the lactation curve (Flower & Weary, 2001; Roth et al., 2009; Costa et al., 2016)

From this evidence, it appears that calves grow better if kept with their mothers and eat less concentrates in

total up until weaning. However, the extra concentrate intake is more than compensated for with 14 kg extra milk per day from the mothers if they are separated. This, together with the information that growth rates from automatically fed calves increase after weaning compared to suckled calves, means that the overall production effects of separating from birth heavily support separation. Separated calves with restricted access to whole milk, or those fed milk replacer have not been found to have such favourable growth (Roth et al., 2009; Lee et al., 2009) and management beyond weaning becomes an increasingly important factor for growth as time increases from weaning, so longer-term separation effects are harder to determine. As the behavioural effects of separation appear to be evident, but temporary, especially from the mother's perspective, the positive performance effects support early separation.

Summary of the evidence

Acronyms: BW=Body Weight; MR=Milk Replacer; WM=Whole Milk; DMI=Dry Matter Intake

Stehulova et al. (2017) Czech Republic	
Population:	Beef cow-calf pairs immediately after weaning at 151 to 274 days of age
Sample size:	50 pairs of cows and calves, (27 males and 23 females)
Intervention details:	Observation of weaning behaviour 0–2; 6–8 and 24–26 hours after separation
Study design:	Case Series
Outcome studied:	Frequency of vocalisation and time spent moving
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • Frequency of vocalisation was higher in mothers of calves with higher daily weight gain (< 0.01) and in non-pregnant mothers (< 0.01) • Frequency of moving was higher in younger mothers (< 0.05) • In calves, females vocalised (< 0.001) and moved (< 0.01) more than males • Calves with higher daily weight gain also called more (< 0.01) • In cows, vocalisation and movement were correlated (< 0.001) and both increased until 6 to 8 h and then plateaued or declined (< 0.001) • In calves, vocalisations steadily increased until 24 to 26 h (< 0.001) whereas movement remained unchanged in time and was uncorrelated with vocalisations. • Sex of the calf had no effect
Limitations:	<ul style="list-style-type: none"> • Beef cattle only • Quite small population number but enough for statistical power on tested outcomes • No measurements of performance characteristics such as effects on weight gain longer-term

Valnickova et al. (2015) Czech Republic	
Population:	Female dairy calves
Sample size:	40 calves

Intervention details:	Either separated at birth or Access to Mother through colostrum feeding period
Study design:	Cohort Study: 2x2 factorial design. Either separated at birth or access to mother for 4 days, then either single pen housed for 8 weeks or group housed for 8 weeks. After 8 weeks, all calves housed in group pens.
Outcome studied:	<ul style="list-style-type: none"> • Play behaviour observed at 2, 5, 12 weeks old for 6 hours each time when calves from single pens were put in pens with three unfamiliar calves and calves from group pens were placed together in new pens. Also, the calves were placed in an open field and observed for 4 hours on day of movement and 4 hours the following day (when the situation had become familiar). The single calves were placed in the open field with an unfamiliar calf. The group calves were placed in the field together • Growth weights
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • There were no significant effects on the mother by companion interaction either on the amount of play behaviour in any of the tests or on the body weights of the calves • Presence of the mother after birth did not increase later playfulness, with the exception of higher spontaneous play at 12 weeks of age • When calves were housed in groups of 4, they played more in the home pen on week 2 and 5 than individually housed, single calves of the same age • Individually housed, single calves were more playful during open field tests and social tests on week 2 and 5 • At 8 weeks, single calves that were placed in a new pen with three unfamiliar calves played more than twice as much as grouped calves that were just moved to a new pen with familiar companions • At day 4, calves housed with mothers were heavier than calves separated immediately after birth from mothers (49.2 ± 1.2 vs. 43.8 ± 1.7 kg). This continued until the end of the second week when there was no difference seen. This may be due to the additional gut epithelial protection provided by the cellular and cytokine components of colostrum in the early days after birth (Jaster, 2005) • Grouped calves grew better by 8–10 kg until week 10 for at least 2 week after relocation or mixing at week 8. The difference being around 10% of body weight, or 15 kg. It was discussed that this may be due to different feeding amounts rather than an effect from grouped accommodation
Limitations:	<ul style="list-style-type: none"> • Very small numbers of animals per group • As the “different” results of play were separated by weeks apart, it is impossible to tell whether or not this is significant. Play hours may be different for other cohorts in other environmental situations

	<ul style="list-style-type: none"> • The play behaviour during observed times are snapshots in time of specific interventions; either in novel situations or joining familiar pen mates in new pens. There is no discussion of a “baseline” play value from each group when not being observed or whilst not in novel situations. This makes it difficult to evaluate the significance of the findings • The experimental design is complex, with many factors; removed from mother at birth and 4 days after birth, housed, single or group, play in novel surroundings, play with unfamiliar calves and play with familiar calves (in the case of the grouped calves). Observations were difficult to distinguish mother/calf separation effects on play, as separation and intervention (4 days and 2, 5, 12 weeks) were a long time apart • Long term performance characteristics (growth) are no different between groups • The conclusions of the research group appeared to be biased towards early mother interactions and group housing, as they placed more significance of their conclusions on individual week observations and not those over the whole experimental period
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Lee et al. (2009) South Korea	
Population:	Female, Holstein dairy calves
Sample size:	20 calves: n=10 in each intervention group
Intervention details:	Whole milk feeding vs. milk replacer with similar composition to whole milk. Fed (1.8 L/feeding) for 4 times daily for the first 25 days of age. Feeding frequency was reduced to 3 times daily for next 5 days, then to 2 times daily for next 14 days, and then to once daily during the last 5 days of the pre-weaning period.
Study design:	Cohort Study
Outcome studied:	Feed intake, growth and health (presence of any disease symptom other than none)
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • At weaning (day 49) and postweaning (day 70), BW was greater by 7 kg (P = 0.03 and P = 0.02, respectively) in calves fed WM than in those fed MR • Mean DMI from both solid and liquid feeds was not affected by the treatments • Body weight gain efficiency during preweaning and overall was improved by 0.48 kg/day (P = 0.001 and P = 0.002, respectively) in calves fed WM than in those fed MR • There was no difference in health between the groups
Limitations:	<ul style="list-style-type: none"> • n=10 per intervention group is extremely low for reliable confidence intervals for this experiment. Although well designed, it lacks power for solid conclusions • Although this study does not particularly address the issue of separation from mother at birth, many of the other

	papers address growth effects on calves. One of the main questions this raises is the growth effects of whole milk vs. milk replacer, as many separated calves would be fed milk replacer. This study suggests that whole milk does affect growth rates pre-weaning and will be a confounding factor when addressing growth between separated and mother fed calves
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Grondahl et al. (2007) Norway	
Population:	Norwegian Red dairy cows and calves of both sexes
Sample size:	15 cows and 31 calves
Intervention details:	Allowed access to mother until weaning at 6–8 weeks of age
Study design:	Case Report
Outcome studied:	Body weight of calves weekly from birth to 13 weeks Slaughter weight of male calves Health to slaughter
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • No observations of poor health were recorded for this cohort of calves • Growth weights up to 13 weeks were 0.9–1.3 kg/week • Mean slaughter weight of 56 bulls from this farm (the 31 experimental calves included) was 301 kg, with a mean slaughter age of 15 months. The author compares this to a national database slaughter weight average of 291 kg in 19.2 months, over a similar period of time (2003–2004)
Limitations:	<ul style="list-style-type: none"> • Very small population number • No comparisons were made with separated calves • Comparisons were made to national database recordings which may be highly unreliable due to non-aligned definitions or inconsistent recording, feeding strategies and many other factors over many different farm situations. It is not known how this farm compares in performance with national standards or targets. • Genetics may affect results, as comparisons were made over a whole country database and may not all be Norwegian Red cattle. • Although 31 calves are included as the sample population of calves used for outcome findings, the author averaged slaughter weights of 56 bull calves from the farm rather than just the 31 calves mentioned in the materials and methods.

Weary & Chua (2000) Canada	
Population:	Dairy cows and calves
Sample size:	54 mothers and calves: 9 cow/calf pairs in 3 treatment groups
Intervention details:	Grouped into separation from mother at 6 hours, 1 day and 4 days after birth.

	<p>Calves were housed in individual pens thereafter. Animals were video observed and microphone recorded for 40 minutes in each observation period. The following periods were recorded:</p> <ul style="list-style-type: none"> • 40 minutes before separation (cow and calf) • At 0, 3, 6, 9, 12, 15, 18, 21 hours after separation (mother) • For 21 hours continuously after separation (calves)
Study design:	Cohort Study
Outcome studied:	<p>Calf behavior: movement, time standing, time head out of pen Cow vocalisation Calf weight gain Cow milk production Calf disease treatments</p>
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • Cows and calves have increased behavioural responses as separation time from birth increases. • Calves separated at 1 day and 4 days spent more time standing, moving and with their heads out of the pen than those separated at 6 hours • After separation, cows in the 4 day separation group called at approximately 4 times the rate of those separated at 6 h or 1 day ($P < 0.01$)
Limitations:	<ul style="list-style-type: none"> • Small population sizes in each group • Experiences on one farm may not be representative compared with other farms as management protocols may differ (feeding times, tractor noise etc. may affect displayed behaviours farm by farm for instance)

Flower & Weary (2001) Canada	
Population:	Holstein dairy cow/calf pairs
Sample size:	48: 24 cow/calf pairs (n=12 pairs per intervention group)
Intervention details:	<p>Separation from mother at 1 day or 2 weeks after birth Calves with mothers fed ad lib from them (cows were milked 2 x daily also) Separated calves were fed 5% bodyweight of "milk" (presumably, whole milk), twice daily</p>
Study design:	Cohort Study
Outcome studied:	<p>Cow and calf vocalisation, movement, time spent with head outside pen Milk volume from cow Calf social interactions with peers after separation Calf growth weights</p>
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • After separation, cows from the late separation treatment group showed higher rates of calling, movement and placing

	<p>the head outside the pen, than cows in the early separation group</p> <ul style="list-style-type: none"> • Parity did not influence cow behaviour • During the first 2 weeks after calving, cows in the late separation group (i.e. still with their calves) yielded around 12 kg less milk at milking, a difference at least partly due to the milk consumed by the calf • Milk yields from days 15–150 did not differ between the two groups • After separation, calves in the late separation group moved and placed their heads outside the pen more often than early separation calves • During the first 14 days after birth, late separation calves gained around 13 kg more in weight than those separated early. Measurements stopped at 28 days of age, when this gap was still maintained at 13 kg • When introduced to an unfamiliar calf at 6 weeks of age, calves from the late separation group showed more licking and head rubbing behaviour towards the unfamiliar calf than did those calves separated early, suggesting they were more confident or knowledgeable of social interactive behaviour
Limitations:	<ul style="list-style-type: none"> • Small population numbers • Experiences on one farm may not be representative compared with other farms as management protocols may differ (feeding times, tractor noise etc. may affect displayed behaviours farm by farm for instance) • Mother fed calves grew at better rates but separated calves were only fed twice daily and at 5% bodyweight. Current recommendations are to feed ad lib or 3 x daily rather than 2 x daily for optimum growth rates (Jones & Heinrichs, 2011)

Perez et al. (1985) France	
Population:	Friesian dairy cows and calves
Sample size:	60 cows and 9 calves
Intervention details:	<p>Separation at birth; Fostering over limited time and suckled; Group housed and fostered.</p> <ul style="list-style-type: none"> • n=20 cows per group, 2 groups had 3 calves/group allocated • Suckled group allowed access to mother until 15 months of age. Group 1 were cows and 3 alien calves, housed in one pen and fostered over 2 weeks, and kept in this pen afterwards • Group 2 were tethered and fostering occurred over 18 hours. Suckling was allowed twice a day afterwards • Group 3 were separated immediately after birth and milked twice a day thereafter

Study design:	Cohort Study
Outcome studied:	Prolactin (hormone released by the brain stimulating milk production) response (measured by blood radioimmunoassay) to mammary stimulation at day 112 after birth Mother-young relationships observed at day 45 for one day Position of calf when drinking from mother
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • Group housed cows were maternal and selective to their fostered calf • Tethered cows were not selective to their calf but allowed suckling access to others • Separated cows did not allow other calves to suckle at 45 days post-partum • Prolactin response was “low” in the separated group • There was no prolactin response in the suckling groups
Limitations:	<ul style="list-style-type: none"> • Small population sizes in each group • The three groups bear no relation to each other in management. We do not know the nutritional protocol in each group; the availability of feed to cows and calves; the environments are different and may affect behaviours. Management may also differ in terms of labour interactions with each group, possibly affecting behaviours • The observation recording was measured on just one day. This may not be enough to reflect the outcomes required. Other factors may influence behaviour on a single day on a farm; noisy deliveries, differences in labour personnel and other situations may affect the measured responses. • How was the response to prolactin measured? • Mammary stimulation and prolactin response are related to insulin-like growth factor 1 and bovine somatotropin (circulation amounts and receptor expression). This has a feedback mechanism with suckling and differs through the lactation curve: this is likely to be affecting the prolactin responses more than behaviour

Marchant-Forde et al. (2002) United States of America, United Kingdom, Canada	
Population:	First to fourth parity Holstein dairy cow/calf pairs
Sample size:	12 cow/calf pairs
Intervention details:	Separation from mother 24 hours after birth and movement to individual pen (calves) in another building
Study design:	Case Report (recording vocalisation and playback to mother)
Outcome studied:	Whether or not vocalisation is specific to the mother’s own calf Heart rate change, head movements, ear movements of calf and mother
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • Cows had increased heart rate and ear movements when

	<p>played any calf's voice</p> <ul style="list-style-type: none"> • Cows had less head movements when played their own calf's voice • Calves showed more head movements and less ear flicks when played any cow's voice • Calves had more ear movements and greater heart rate change when played their mother's voice vs. another cow • Dairy calves in this experiment were able to distinguish their mother's voice from others from only 24 hours' exposure
Limitations:	<ul style="list-style-type: none"> • Unknown how much time is required for mother to learn the calf's vocal signature • Small population size • Although there was reported white noise in the background, this could have been influenced by background management routine (noise in the barns) • There is no comparison with animals separated at birth and unable to exchange sounds

Roth et al. (2009) Switzerland	
Population:	Dairy calves
Sample size:	57 calves in 4 groups: 25 Holstein Friesian and 32 German Red Pied
Intervention details:	<p>Groups: formed dynamically (calves entered at different times) not exceeding 17 per group. One breed was in one barn and one in another in identical size and layout pens:</p> <ol style="list-style-type: none"> 1. n=14 unrestricted access to mother to 91 days 2. n=15 Allowed access to mother twice daily for 15 minutes before milking to 91 days 3. n=14 Separated from mother and access to automatic feeder 6 times daily. Weaned at 91 days 4. n=14 Separated from mother and access to automatic feeder 2 times daily. Weaned at 91 days
Study design:	Cohort study
Outcome studied:	<p>Behaviour (by video observation for 4 hours per day on two consecutive days at weeks 4, 10 and 15): time bouts of sucking and whether calves go to own mother or not</p> <p>Milk yield of cows (groups were organised by parity)</p> <p>Health score (Trained evaluators observed and recorded the general health, state of eyes, nose, ears, navel, coughing, dirtiness in scores of 0 to 2, the higher scores being poorer health) to 13 weeks: 0–2 scale due to presence of disease symptoms</p> <p>Weight of calves weekly to 16 weeks</p>
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • 26/28 automatically fed calves showed cross-sucking behavior vs. 1/29 from the suckled groups • Total duration of feeding was twice as long for mother fed

	<p>calves vs. automatically fed</p> <ul style="list-style-type: none"> • Mother-fed calves tended to have higher disease rates (respiratory and diarrhoea) than automatically fed but veterinary required treatments did not differ between groups. Animals were observed for disease by “caretakers” and only ones deemed serious were referred to a veterinarian. Caretakers could treat and diagnose • Calves fed by the mother until weaning gained approximately 25–28 kg more than automatically fed calves (significant at $P < 0.0001$) • Automatically fed calves gained more weight (approximately 0.4 kg/day at 4 months) after weaning than mother fed (significant at $P < 0.0001$) • Calves allowed to feed more than twice per day gained more weight than those fed twice per day in either group • Calves from the mother fed group consumed 1.75–3 kg concentrates in total. Calves from the automatically fed group consumed 21–22 kg in total until weaning • Milk yield in mother fed calves was 14 L/day less than automatically fed. Unfortunately, no recording of 305 day yield was recorded and no economic cost/benefit was noted by the authors
Limitations:	<ul style="list-style-type: none"> • Breed genetics and barn design may have influenced the groups as well as the studied variables • The health results may have been due to individual outbreaks in pens rather than the mother/auto fed milk (e.g. coccidiosis or rotavirus) • Calves entering pens dynamically could affect social interactions and therefore feed intakes as well as the variables studied • Although the amount of concentrate feed consumed by mother fed calves was 21 kg lower, the yield loss of 14 kg/day would mean a far greater economic loss than that regained by unconsumed concentrate

Johnsen et al. (2015) Norway	
Population:	Norwegian Red dairy cows and calves
Sample size:	32: 16 cow/calf pairs, n=8 pairs in each intervention group
Intervention details:	Cows and calves separated at weaning by either a fence line (able to still have visible and audible contact) or solid wall (only audible contact)
Study design:	Cohort Study
Outcome studied:	Studied behaviour at 0, 1, 2, 3 and 4 days after separation for 4 hours each time Vocalisation: pitch and number of calls

	Head posture of calf Ear movement of calf
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> Calves with complete separation appear to vocalise and make more head/ear movements at weaning than partial separation. Fence line group displayed approximately 10–20 times less vocalisation behaviour than solid wall group Fence line group displayed approximately half as many head and ear posture movements than the solid wall group
Limitations:	<ul style="list-style-type: none"> Small population numbers Unknown whether or not management or background noise may have affected the results There was no comparison with non-audible separation

Kisak et al. (2011) Czech Republic	
Population:	Holstein Friesian primiparous dairy cows and their calves
Sample size:	100, or 50 cow/calf pairs: Group A n=16; Group B n=18; Group C n=16
Intervention details:	<p>Group A weaned at 7 days Group B weaned at 14 days Group C weaned at 21 days</p> <p>Calves were then moved to individual pens until 56 days of life and then to group pens</p> <p>After the calves were moved to individual pens, they received a milk replacer from a bucket with nipples. Until day 27 of life the calves received 6 L of milk replacer and from day 28 to 56 8 L of milk replacer. From day 7 to weaning the calves were offered a concentrate mixture and lucerne hay ad lib. They received 1.5 kg of concentrate mixture per day and lucerne hay in free choice from weaning to 3 months of age. A breakdown of replacer is not described.</p>
Study design:	Cohort Study
Outcome studied:	Body Weight of calves at 7, 14 and 21 days, 56 days and 3 months Daily milk weights of cows (milked twice daily)
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> In the period from birth to weaning at the age 56 days the calves of group A reached an average daily gain of 0.35 ± 0.16 kg, calves in group B had 0.46 ± 0.13 kg and the animals of group C attained 0.54 ± 0.14 kg ($P < 0.01$). The difference between groups A and C was highly significant The average daily gains for the period from birth to 3 months of age were statistically different among groups ($P < 0.001$). The lowest gain was recorded in animals of group A

	<p>(0.55 ± 0.11 kg) and the highest gain in calves of group C (0.74 ± 0.12 kg)</p> <ul style="list-style-type: none"> • There were significant differences in live weight of calves at 3 months from groups A to C: (93.7 ± 9.3 kg, 100.5 ± 13.2 kg, 108.2 ± 10.5 kg, P < 0.01) • The first calf heifers of group A displayed the trend of the highest milk production during the first 4 months of lactation (3163.1 ± 460.4 kg, 2979.1 ± 314.9 kg, and 2853.5 ± 331.5 kg) • Although this was a trend, there was no significant difference in milk volume from cows in any of the three groups (this is a study size effect: 330 kg of milk is a significant economic amount) • There was no recorded difference in health of calves from any of the three groups
Limitations:	<ul style="list-style-type: none"> • Weaned later than current dairy practices on most farms (weaned at weeks old rather than hours) • No comparison with separation at birth • All heifers (primiparous cows) and may be inexperienced and bias results • Effects of milk replacer amounts eaten may affect growth more than when weaning occurs, due to availability and composition of milk and replacer

Costa et al. (2016) Canada	
Population:	Dairy cows and calves
Sample size:	197 papers reviewed
Intervention details:	Separation from mother at birth; group housing; individual pen housing; suckling from mother
Study design:	Review of Cohort Studies and Case Series
Outcome studied:	Effects on behaviour, growth rates and health of calves separated at birth and kept in either individual or group housed pens
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • During the milk feeding period, the calf relies on social cues from the dam and other conspecifics that influence behavioural development • Calves housed in groups are better able to interact with peers and actively make social choices to be with them, whereas individually housed calves do not and are fearful of new contacts • Social relationships are long lasting • Calves from socially reared groups react with less stress responses to novel situations than individually reared calves • Calves that are socially reared respond better to cognition learning tests than individual or paired housing calves

	<ul style="list-style-type: none"> • There is much evidence supporting the relationship between social rearing and weight gains/feed intakes vs. individually housed calves • Out of 19 publications, none showed negative social effects from group housing and 19/32 parameters measured showed positive effects • Competitive behaviour around teats is common in group housed automated feeder systems, especially when feed is restricted but reducing the ratio of teats to calves helps this • There is conflicting evidence on calf health and group vs individual systems, with some papers reporting less disease risk in group housing and some reporting no difference.
Limitations:	<ul style="list-style-type: none"> • No effects on the mother (milk yield, social effect) were reviewed • No search strategy was recorded

Jensen (2011) Denmark	
Population:	Holstein Friesian dairy cows and their calves
Sample size:	74: 38 cows and 36 calves
Intervention details:	All animals housed in individual pens together (cow and calf) for the first 12 days post-partum Observed over 24 hours on days 3, 7 and 11 Removed from the pens for 3 hours on days 4, 8, 12 and observed for 3 hours after returning
Study design:	Case Report
Outcome studied:	Time spent licking, sniffing and at locomotor play
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • Cows spent less time sniffing and licking their calves over increasing days (59–49 minutes) • Cows spent more time licking other cows over increasing days (1–11minutes) • Calves spent more time licking and sniffing at their mothers over increasing days (4–9 minutes) and more time playing with increasing days (1–4 minutes) • Returning calves spent more time licking their mothers • Mothers spent less time licking their calves after returning • This suggests that mothers have an increased preference to socialise with other cows than their calves within 3 hours of separation
Limitations:	<ul style="list-style-type: none"> • Separation/returning experiment makes bold conclusions from such a small population number and little time apart/spent observing • No vocalisation observed • No comparisons made with group housed animals

Wagner et al. (2015) Netherlands	
Population:	Dairy cows and calves
Sample size:	Total 26 calves, 15 mothers (from groups C and D) Separated calf group A n=6 Separated calf group B n=5 Suckling 2 x daily group C n=9 Suckling ad lib group D n=6
Intervention details:	Separation after 24 hours from birth: All weaned at 12 weeks Group A: Separated at 24 hours and fed 6 x daily by automatic feeder Group B: Separated at 24 hours and fed 2 x daily by automatic feeder Group C: Access to suckle mothers for 15 minutes, 2 x Daily Group D: Allowed ad lib access to mothers
Study design:	Cohort Study
Outcome studied:	Heart rate, number of movements, number of interactions with a ball, and blood cortisol levels in cows and calves during a period of isolation 1.5 months after weaning
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • Group A calves and group D cows had the lowest heart rates on isolation • Group D cows had the highest change in cortisol levels (but not reported as significantly different) • Group D cows spent more time moving during isolation • Authors concluded that mothers with suckled calves after separation had more stresses, resembling a “reactive coping style”
Limitations:	<ul style="list-style-type: none"> • Very small population numbers • Isolation period was 1.5 months after separation, with many other potential factors that could have influenced social behaviour other than the variable of mother/calf interaction pre-weaning (e.g. social peer relationships of new pen groups, management routines, feeding changes, etc.) • Size of calves may have varied considerably if group B and C had such restricted access to feed pre-weaning. This could have affected physiological parameters • Authors assumed that trends were significant in their conclusions

ShinJae (2013) South Korea	
Population:	Dairy cows and calves
Sample size:	60 (n=30 cow/calf pairs)
Intervention details:	Partial (separated at birth but housed adjacent to calves with a solid wall between so there was audible and olfactory contact) and

	complete separation (separate barn) between mother and calf, for duration of experiment. Group 1. Partial separation in one barn Group 2. Complete separation in another barn
Study design:	Cohort Study
Outcome studied:	Vocalisation, standing and lying time of mother; sniffing time and frequency Video observation for 10 hours on days 1, 6 and 11 after partial or complete separation
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • Cows and calves in partial separation group had higher vocalisation frequency than complete separation group • Cows in complete separation group showed significantly more lying time and less standing and sniffing time than other group • All else was not significantly different • Authors suggest partial separation implies more behavioural effects on cows and calves than complete separation
Limitations:	<ul style="list-style-type: none"> • Small population numbers • Groups kept in different barns with potentially different management routines and feed, which may affect stresses and behaviours

Wagner et al. (2012) United Kingdom	
Population:	Dairy heifers (integration into the dairy herd as first lactation cows)
Sample size:	26 primiparous dairy cows
Intervention details:	Weaned at 12 weeks then group penned for integration into the herd at 25 months Group A: n=5 Separated at birth and automatically fed 6 x daily Group B: n=5 Separated at birth and automatically fed 2 x daily Group C: n=9 Access to mother 2 x daily for 15 minutes to weaning Group D: n=7 Access to mother ad lib to weaning
Study design:	Cohort Study
Outcome studied:	Video observations for 33 hours after integration into the herd Social interactions Faecal cortisone
Main findings: (relevant to PICO question):	<ul style="list-style-type: none"> • Heifers that had access to mothers tended to be more submissive in the herd (P = 0.023) • All other results were not significant or trends in very small populations
Limitations:	<ul style="list-style-type: none"> • Very small population numbers • Authors reported and discussed non-significant results (>P =

	<p>0.05 or even $P = 0.1$) as if they were significant in the discussion</p> <ul style="list-style-type: none"> • Some of these (recognition of mother after 2 years in the herd) were based on $n=1$ populations • Author conclusions were based on non-significant results
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Appraisal, application and reflection

General Views

Of the 16 papers reviewed, 14 addressed populations of dairy cattle and 2 included beef animals (Stehulova et al., 2017; Valnickova et al., 2015). The latter articles were included as the methodology of the experiments were similar to those of the dairy practice articles and thus, results could add to this knowledge bank. The papers reflect global practices in mother and calf management, as papers were published from Latin America, North America, Asia and Europe.

Separation from the calf within 24 hours of birth appears to be very common (USDA, 2014) and many of the articles studied reflect this practice but some separated the calf 1–2 weeks later (Flower & Weary, 2001; Kiskak et al., 2011).

Other management aspects reflect current dairy practices after separation such as keeping calves in individual pens shortly after birth, group housing calves and feeding them through an automatic feeder (USDA, 2014). If suckling is allowed to happen, then tethering cows is far less common in Western Europe but is still seen in Eastern Europe and Canada. However, comparing groups of calves combining all of these in one article produces too much management variation, especially when comparing growth or behaviour (Perez et al., 1985).

Ultimately, it is extremely challenging to fully evaluate the “stresses” involved in breaking the maternal bond between cow and calf, as many of the psychological aspects cannot be communicated or quantified. Therefore, the research groups have attempted to make a “best guess” by using some characteristics that can be measured, such as head rubbing, vocalisation, etc.

Behaviour

When studying behavioural outcomes, such as vocalisation, movements and lying times, it is preferable to have comparable conditions for both intervention groups. However, in many articles, the groups were either kept in different barns (Perez et al., 1985; Jensen, 2011; Johnsen et al., 2015; Wagner et al., 2012) or management routines have not been discussed sufficiently to explain the effect of background noise. Feeding and labour management can affect movements and vocalisation as cattle respond to people or machinery/feeding times. Only one article addresses the effect of “white noise” in their discussions (Marchant-Forde et al., 2002).

Many of the papers have very small population numbers in each group, with eight or less mother-calf pairs in each treatment group. This makes it difficult to interpret the statistical power of the results: P-values are often reported but confidence intervals are not, making discussion statements difficult to conclude from. This depends on the outcome studied: if these are growth rates, for instance, it is very difficult to tell from such small populations but if the outcome is number of vocalisation observations, then these are larger in number and more reliable conclusions can be drawn.

This becomes increasingly difficult when authors discuss results which are not scientifically significant ($P > 0.05$) or even as a trend ($P > 0.10$). Two of the papers report favourable results towards non-separation in their conclusions based on numerical differences when error bars clearly overlap (Wagner et al., 2015; ShinJae, 2013).

Experience of the mother may be a significant variable when assessing behaviours between mother and calf, so parity should be recorded clearly in each paper. However, the behaviour of heifers specifically is studied in only one article (Wagner et al., 2012).

When assessing the behaviour of calves kept in group pens, the affect of calves entering the pens at different times (when they are old enough to join the group) may affect behaviours such as head movements, number

of movements, lying times, licking, sniffing, etc. This is only specifically addressed in one article (Roth et al., 2009).

Performance

When assessing growth rates and milk yields, there is far less room for error in recording, as these are absolute variables. Therefore, the papers addressing these outcomes are able to interpret the results with more reliable statistical discussion. However, due to such small population numbers, variables such as milk yield are unlikely to produce significant differences at $P < 0.05$ which can make solid conclusions hard to justify.

Growth rates of calves were often measured pre and post weaning and compared with either separation from birth, or access to the mother. In the separated groups, experimental methods tended to compare restricted and ad lib access to feed. This may have affected the reliability of results as it further reduced the population numbers of each group and added more confounding variables: growth is related directly to energy and protein intakes.

Growth of dairy heifers also varies with time: they tend to grow slowly in the first few weeks, accelerating in the later months and tailing off towards integration into the lactating herd (Coffey et al., 2006). Because of this, separating the calves at 2 weeks, 6 weeks or 12 weeks and comparing growth rates may have varying effects on future growth curves for those calves. Therefore, comparing directly between these and calves separated at birth may not reflect direct comparisons. Modifying the methods to include recording growth by smaller increments of time (each week, for example) may help to resolve this issue.

Again, similar to behaviours, growth and feed intakes may be affected by daily feeding routines/timing and social movements in pens, so in group housed situations, the comparisons of calves in one barn or pen vs. another may have more variables to consider than just separation from the mother.

Milk yields of cows are easy to record, as these are closely monitored on a daily basis when milking. Therefore, results such as 14 kg less milk per day (averaged over the pre-weaning period of 91 days) with ad lib suckled calves is a more reliable result (Costa et al., 2016; Roth et al., 2009). This result was obtained comparing similar parity and breed cows, chosen at random and grouped in similar proportions in pens but not mentioned to have been chosen by previous lactation yields. The cows were kept in identical pens and fed the same rations. The separated calves ate whole milk; the ad lib group averaging 8–10L intake/day and restricted group eating an average of 8 L/day. It is impossible to measure the actual intake of the suckled calves, making it more difficult to directly compare factors affecting growth rates of the two calf groups.

Separation at different points of early lactation may have effects on the long-term lactation curve overall but no authors have suggested or investigated this aspect over a 305 day lactation. There are more metabolic demands in the first 14–21 days in milk (McArt et al., 2012; Duffield et al., 2009), so separation beyond the first 48 hours may affect yields and lactation curves in varying ways depending on disease status, nutritional status, management and other factors. So comparing yields from cows separated at 1 and 2 weeks post calving (Kisak et al., 2011) may not be directly comparable with those separated at birth. Larger population numbers would be required to get reliable results.

Summary

Although suggestions can be made from the behaviour results reported in this review, it is difficult to draw a reliable conclusion that suckling may be beneficial over separation at birth from a mother/calf stress perspective. It seems that calves do vocalise and seek their mothers after separation the longer access they have to them but the actual stress impact of this is harder to determine. Mother-offspring bonding is an emotive human concern as humans have such vulnerable and helpless babies relative to ruminants. Assessing the impact of separation in cattle cannot be humanised, as their offspring are able to stand and find their own food within minutes of birth. Researchers can use a limited number of observations and physiological measurements to indicate stress but emotion will always be difficult to evaluate.

Due to the significant economic loss of milk when calves are allowed free access to their mothers and the increased risk of Johnes' disease when they are, it is clearly economically beneficial to separate them within 24 hours. Evidence supports growth rates in calves before weaning are better when allowed free access to their mothers but from weaning to joining the dairy herd, the overall growth can be improved post weaning

by early separation and ad lib access to an automated feeder. To make a general conclusion that separation results in better growth rates however, comes with words of warning: there are so many other confounding management factors to consider until the calves reach the milking herd, for example feed quality and access, parasitism and disease, that it would not be wise to assume that separation alone affects such long term ends.

Methodology Section

Search Strategy	
Databases searched and dates covered:	3 databases: <ol style="list-style-type: none"> 1. PubMed on NCBI Platform; 1980–2018 2. CAB Abstracts on OVID Platform; 1973–2018 3. Google Scholar; 2000–2018
Search terms:	<ul style="list-style-type: none"> • PubMed on NCBI Platform: <ul style="list-style-type: none"> ○ ((mother) AND (((cow\$ OR cattle OR bovi*))) AND ((calf OR bovi* OR calve\$))) AND separat* • CAB Abstracts on OVID Platform search 1973–2018: <ul style="list-style-type: none"> ○ mother ○ cow* OR cattle OR bovi* ○ calf OR bovi* OR calve* ○ separat* ○ 1 AND 2 AND 3 AND 4 • Google Scholar <ul style="list-style-type: none"> ○ (cow mother calf calve\$ separation)
Dates searches performed:	<ul style="list-style-type: none"> • 9 January 2019 (PubMed and Google Scholar) • 13 January 2019 (CAB Abstracts)

Exclusion / Inclusion Criteria	
Relevance to PICO, sufficient evidence level, answers the clinical question	
Exclusion:	Non-bovine; Cellular and molecular effects; In vitro work; behavioural responses recorded a long time after separation event (>30 days) Conference proceeding with such poor quality science and report that it was impossible to review
Inclusion:	Bovine; Behavioural; Performance outcomes

Search Outcome					
Database	Number of results	Excluded – Relevance to PICO	Excluded – Repeated	Excluded – inadequate scientific reporting	Total relevant papers
PubMed	45	38	0	0	8
CAB Abstracts	143	132	7	1	3
Google Scholar	1007 on first 10 pages	1000	2	0	5
Total relevant papers when duplicates removed					16

CONFLICT OF INTEREST

The author declares no conflicts of interest.

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