Influence of lying surface, milking system, age and productivity on lying times of Dutch dairy cows

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Summary

Background and aims: In general, dairy cattle spend between 8 and 15 h/d lying down. However, due management factors cows can be deprived to lie down. When a cow spends more time lying down, stress on feet and lameness will reduce, while blood flow to the mammary gland as well as feeding activity will increase and overall cow health will enhance. The objective of this study is to describe the influence of the lying surface (deep bedded or mattresses), milking system (milking parlor or automatic milking system), age (primiparous or multiparous) and the milk yield on the lying times of commercial Dutch dairy cows.

Materials & Methods: On 17 farms, lying times were measured during the first 28 days postpartum by Nedap smarttags and computed into 3 categories: total lying time/d, the number of lying bouts/d and the average duration of a lying bout.

Results: Cows on deep bedded lying surfaces spent more time lying down, had less lying bouts and the average lying bout duration was longer compared with cows housed on mattresses (662±7.8 min/d, 6.77±0.1 bouts/d, 105.9±1.85 min/bout vs. 611±9.7 min/d, 7.17±0.13 bouts/d, 90.4±1.85 min/bout, $P<0.01$). Cows milked with an automatic milking system spent more time lying down, had more lying bouts of longer duration compared with cows milked in a milking parlor (657.5±13.8 min/d, 7.15±0.19 bouts/d, 102.4±3.54 min/bout vs. 637.6±6.8 min/d, 6.93±0.09 bouts/d, 97.7±1.44 min/bout $P<0.01$). Multiparous cows spent more time lying down, divided their lying time in less bouts of longer duration compared with primiparous cows (654.3±7.5 min/d, 6.78±0.09 bouts/d, 102.1±1.59 min/bout vs. 598.1±15.5 min/d, 7.90±0.23 bouts/d, 84.1±3.32 min/bout $P<0.01$). When days in milk increase, the difference between multiparous and primiparous cows decreased. Moreover, the results of this study showed that when cows spent more time lying down, they will have a higher milk production.

Conclusion: In conclusion, cows spend more time lying down on deep bedded lying surfaces, when they get milked with an automatic milking system and when they are multiparous. In addition, when cows have a longer resting period, the milk production will improve.

Introduction

Dairy cows spend about 50% of their daily time lying down, which is divided in 14 bouts (Dechamps 1989, Gomez, Cook 2010, Tucker et al. 2009a, Charlton, Haley et al. 2014). An average cow spends about 11.8 h/day resting. When a cow spends more time lying down, stress on feet and lameness will reduce, while blood flow to the mammary gland as well as feeding activity will increase and overall cow health will enhance (R. J. Grant 2006, Cook 2002, Cook, Nordlund 2009, Nishida, Hosoda et al. 2004). Several studies (Fisher, Verkerk et al. 2002, Munksgaard, Simonsen 1996) have shown that lying deprivation causes stress resulting in an increase of the basal plasma cortisol concentration. Moreover, research carried out by Munksgaard et al. (2005) indicated that lying time had higher priority than eating time and social contact (Munksgaard, Jensen et al. 2005).

Besides the total lying time per day, the average duration of a lying bout and the number of lying bouts per day are other important parameters. Tucker et al. (2009a) investigated lying times of dairy cows and reported that the duration of an average lying bout was 72 ± 42,6 minutes, with an exponential decline in the number of bouts when the lying period is longer than 80 minutes (Tucker et al. 2009a). In a Canadian study, data was collected from 111 freestall dairy farms. They found an average of 10,5 lying bouts per day(Charlton et al. 2014).

A good bedding must provide softness, thermal comfort and sufficient grip to give the cow the possibility to easily rise up or lie down in the cubicle(Calamari, Calegari et al. 2009). There is a substantial amount of different types of freestall surfaces(Calamari et al. 2009). Van Gastelen et al. (2011) compared four of those different surfaces (box compost, sand, horse manure, and foam mattresses) and found a high variability in resting time between those surfaces. Several studies examined the relationship between lying surface and lying behavior. One study concluded that there was no difference between mattresses (MAT) and straw bedding(Wechsler, Schaub et al. 2000), while others concluded that cows spent more time lying down on deep bedded (DB) surfaces (Tucker et al. 2009a, Calamari et al. 2009, Haley, Rushen et al. 2000, Ito, Chapinal et al. 2014). However, some studies describe more lying bouts per day with shorter average bout duration on well bedded surfaces (Calamari et al. 2009, Tucker et al. 2009a, Haley et al. 2000, van Gastelen, Westerlaan et al. 2011), while others describe less lying bouts with a longer duration per lying bout on well-bedded surfaces (Ito et al. 2014, Gomez, Cook 2010).

Lying time can also be affected by the type of milking system. It has been reported that cows milked with an automatic milking system (AMS) have a lower lying time per day compared with a conventional milking parlor (MP) (Spolders, Meyer et al. 2004). Furthermore, it has been reported that lying times of cows milked in an MP was affected by waiting period before cows can get milked. When cows were longer than 3.7 hours per day away from the cubicles, no farm achieved a lying time of 12 hours per day (Charlton et al. 2014, Gomez, Cook 2010). Milking 3 times a day can increase comfort of high-productive cows and extend the lying time (Österman, Redbo 2001).

Primiparous dairy cows (PC) spent less time lying down and divided their lying time in more bouts (Sepúlveda-Varas, Weary et al. 2014), when compared to multiparous cows (MC).

In addition to the positive influence on animal welfare, longer laying times also have a positive influence on the economic results of a dairy farm. Previous research showed that cows who are prevented to lie down, produce less milk compared with cows who are not prevented to lie down

(Norring, Valros 2016). Another study concluded that when improved lying comfort results in one hour more resting time, the production will increase with 1 to 1.6 kg milk per hour resting time per day (R. J. Grant 2006, R. Grant 2012).

The aims of the present study were to describe the lying times of dairy cows (1) housed on different lying surfaces, (2) with different milking systems, (3) with different ages on Dutch dairy farms and compare the outcomes with previous studies. Furthermore, this study investigates (4) the lying times of high and low productive cows.

Materials and Methods

Farm selection

Between May 2014 and October 2015, data was collected from 17 commercial freestall dairy farms in The Netherlands. This study is a part of a large study of Nedap, Vetvice, Wageningen University and the Faculty of Veterinary Medicine of Utrecht University. The selected farms had deep litter bedding or mattresses in the freestalls and used a traditional milking parlor or a robot for milking the cows.

Data collection

To record the time the cows spent lying down, Nedap Smarttags were attached to the hind leg of each cow. The cows were attached with the tag for at least 6 weeks antepartum until 4 weeks postpartum. For the present study, the data from 3 days postpartum until 28 days postpartum was used. Data collected before day 3 postpartum was useless because most farmers kept their cows 1 or 2 days in the calving pen after calving. The Nedap Smarttag measures the standing, lying and walking behavior of a cow. Nedap Smarttag is a RFID system, which consists of RFID-tag, RFID-reader and processing software. Every cow had a separate Nedap Smarttag with an unique RFID 15 digit code. The Nedap Smarttag is programmed to record the position of the cow (standing or lying) in seconds per 15 min and send data to the ID-controller. The ID-controller is connected with a Process Controller, which analyses the individual data and send it to a PC.

The total lying time per day is the sum of all lying minutes per day. During a lying bout, cows often change from lying to standing position to change their lying posture (Tucker et al. 2009b), which will be counted as a standup. The software made a difference between lying bouts and standups, and because the lying bouts must be derived from the 15 min data, the following definition was applied: (1) The minimum time of a lying bout is 15 minutes. (2) If the time between a lying period and the next lying period (time standing) is less than 15 minutes, both lying periods will be counted as the same lying bout. (3) Start and end time are derived from the lying minutes of the first and the last 15 min period that belong to a lying bout. Using those rules the number of bouts per day and the average bout duration per day is calculated.

The farms were grouped according to 3 parameters: (1)Lying surface: MAT or DB cubicles (the lying surface of DB cubicles consist of sand, chopped straw or sawdust). (2) Milking system: cows are milked by an MP or by an AMS. (3) Age: the cows are PC or MC.

Data selection

In total 2259 cows were monitored. For the category 'lying surface' the farms were excluded when cows can lie on DB cubicles or MAT on the same farm (1 farm). With the exception of dry period, all dairy cows housed on pasture were excluded for category lying surface (5 farms). For the category 'milking system' the farms were excluded if the cows were milked by MP and AMS on the same farm (1 farm). For the category 'age' cows were excluded if the age of the cow could not be determined from the records. Reasons for missing data are: broken hardware or if the Nedap Smarttag was not connected with the ID-controller for 24 hours. When cows had a disease, another abnormality or there was data missing they were excluded from the study. Table 1 shows the number of cows that were used for the different categories. In addition to the sensor data, information was obtained about the lactation (milk yield, kg fat and kg protein). The relationship between milk production and average lying time was investigated.

Data analysis

The data was analyzed using SPSS (IBM SPSS Statistics 24). Data of all parameters (LT, LB and LD) were analyzed using a mixed model with random cow effects and age, milking system, freestall surface and time postpartum (day 3 until day 28 postpartum) as fixed effects, and interaction of age × time postpartum, milking system × time postpartum and surface × time postpartum. If a fixed effect was not significant, it was removed from the analysis. In all models, residuals were examined afterwards to verify normality and homogeneity of variances. Data of production and lying times were plotted in a boxplot. Data is analyzed using an 1-way ANOVA, with average lying time as dependent variable, kg milk as factor and with post hoc testing. The outcome of this analysis is described in the results.

Results

Descriptive data

Of the 2259 cows included in the study, data between 588 and 894 cows was useful (table 1). The mean lying time (±SEM) was 640 ± 4.95 minutes/day divided in 6.9 ± 0.08 bouts with an average duration of 90.0 ± 1.34 minutes/bout. Data of production in combination with correct sensor data was available of 426 cows.

Data of lying time per day was analyzed using a mixed model with random cow effects and with age, milking system, freestall surface, time postpartum and time postpartum × age as fixed effects. Time postpartum was not significant but could not be removed because time postpartum *age was significant. The data was tested for normality by a normal probability plot. The SPSS-model showed that all P-values were <0.001. Data of the number of lying bouts per day was analyzed using a mixed model with random cow effects and age, milking system and surface as fixed effects. The data was tested for normality by a normal probability plot. The SPSS-model showed that all P-values were <0.001. Data of average duration per lying period per day was analyzed using a mixed model with random cow effects and age, milking system and surface as random cow effects. The data was tested for normality by an LOG median probability plot. The SPSS-model showed that all P-values were <0.001. In all models, residuals were examined afterwards to verify normality and homogeneity of variances. There was no relation between the time after calving and one of the parameters.

	Lying surface			Milking system			Age			Productivity
	Total	Deep bedded	Matress	Total	Milking parlour	Robot	Total	Primiparous	Multiparous	Kg Milk (produced 305 days)
LT	742	430	312	738	584	154	613	123	490	426
LB	732	425	307	726	577	149	588	121	467	
LD	894	494	400	887	737	150	762	155	607	

Tabel 1. Summary of numbers of cows per category (LT=lying time/day, LB=lying bouts/day, LD=average bout duration/day).

Lying times and different lying surfaces

The average daily lying time was 663±8.6 min/day for cows housed on DB stalls and 611±8.8 min/day for cows housed on MAT stalls, a difference of 47 min/day (figure 1A). Cows housed on MAT divided their lying time into more bouts compared with cows on DB surfaces (7.2±0.11 bouts for MAT herds versus 6.6±0.12 bouts for DB herds, figure 1B). The duration of a lying bout was lower for cows housed on MAT versus on DB surface (91.8±1.81 min/bout and 107.2±2.00 min/bout min, respectively, figure 1C).

Lying times and different milking systems

Cows milked with an AMS spent more minutes per day lying down compared with cows milked in an MP (657±13.8 and 637±6.8 min/day, respectively, figure 2A). Cows milked with an AMS divided their lying time in more bouts than did cows milked with an MP (7.15±0.19 and 6.8±0.09 lying bouts/day, respectively, figure 2B). The average duration of a lying bout of a cow milked with an AMS is 97.7±1.4 minutes versus 102.4±3.5 of a cow milked with an MP (figure 2C).

Lying times and different ages

The average daily lying time was 598±15 min/day for PC versus 654±7.5 min/day for MC (figure 3A). The gap in lying times between PC and MC is narrowing during the time, the average difference in the first four days is 90 minutes per day, while from day 24 – 28 pp the difference is decreased to 23 minutes per day. PC divided their lying time into more bouts than did MC (7.90±0.23 and 6.78±0.09 bouts/day, respectively, figure 3B). The duration of lying bouts were shorter for PC compared with MC (84.1±3.32 vs. 102±1.59 min/bout, figure 3C).

Lying times and productivity

Of 426 cows, all productive values were traceable. High productive cows spent more time lying down compared with low productive cows (figure 4). Cows who gave 13.000 kg milk or more rested on average 124 minutes more compared with cows who gave 7.000 kg milk or less (754±17.9 min/day vs. 630±13.4 min/day). There was a significant difference between cows who gave 7000 kg milk or less and cows who gave 10.000 kg milk or more ($P<0.009$), the difference with cows who gave between 9.000 and 10.000 kg milk was almost significant ($P=0.06$). To clarify the outcome of this

part of the study, the mean of the results are plotted in a bar chart (figure 5). This diagram shows difference in average lying times between the low and high productive cows.

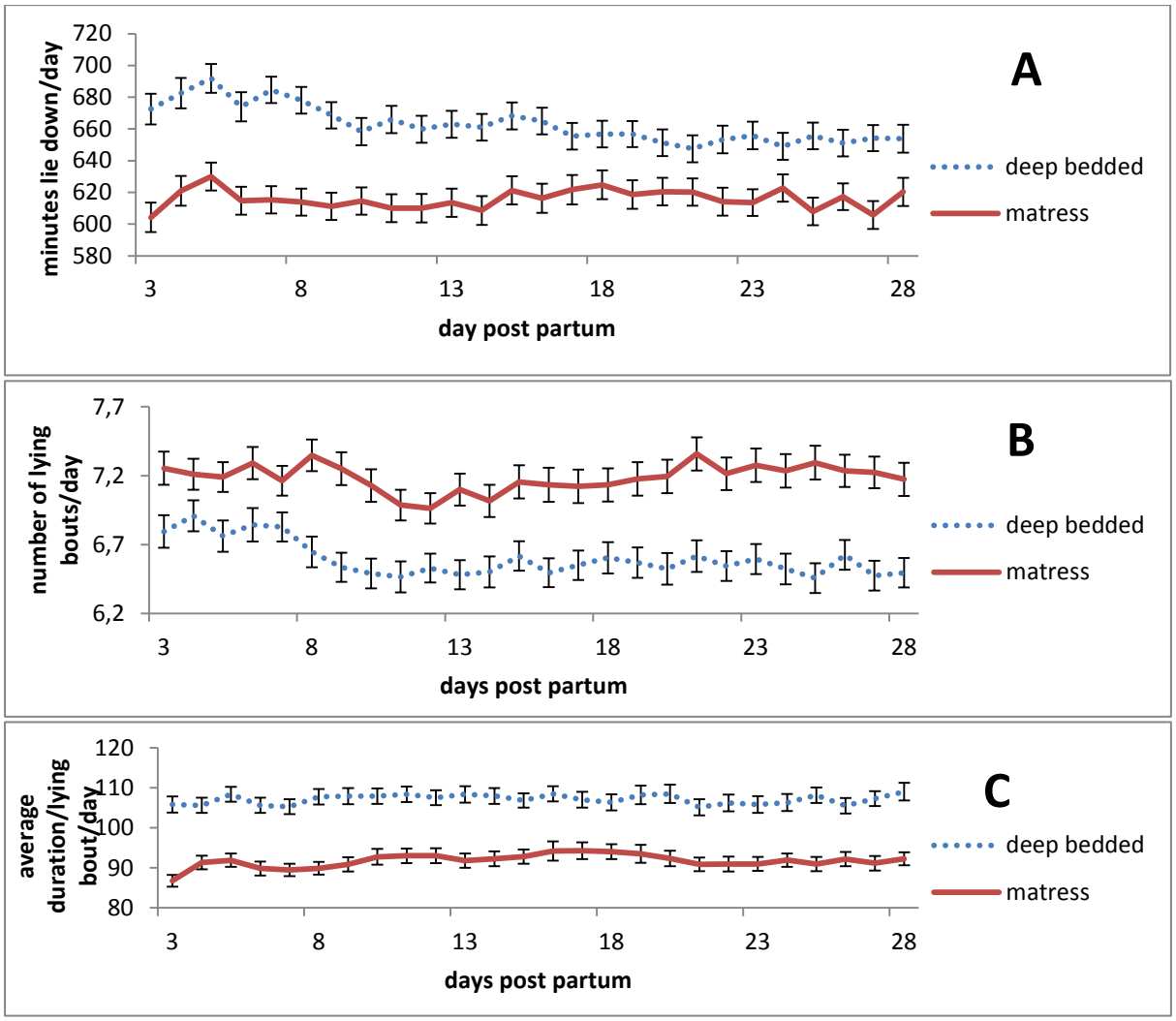

Figure 1. Changes on total lying time (A), the number of daily lying bouts (B), and the average lying bout duration (C) of cows housed on deep bedded or mattresses.

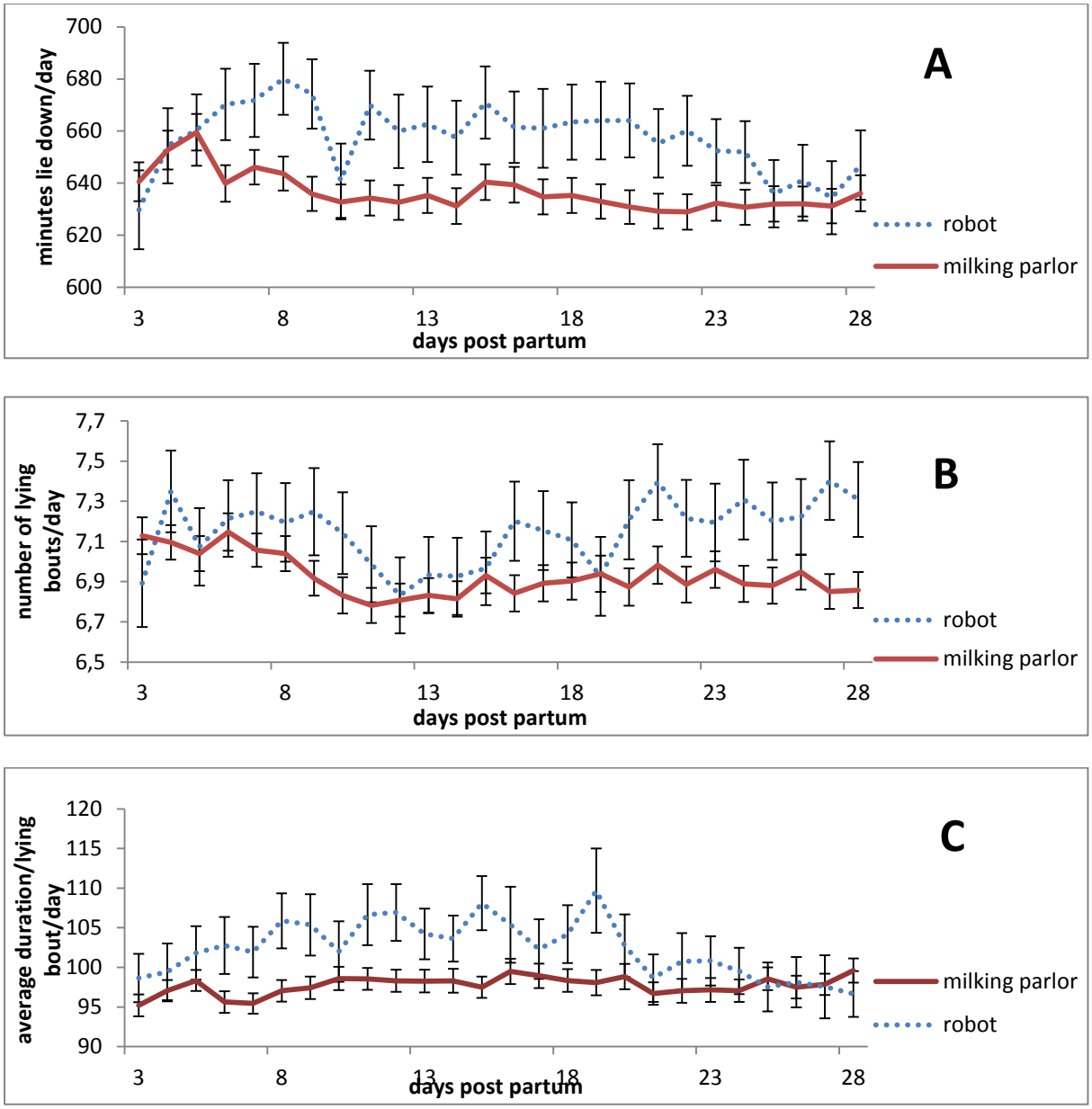

Figure 2. Changes on total lying time (A), the number of daily lying bouts (B), and the average lying bout duration (C) of cows milked by robot and milking parlor.

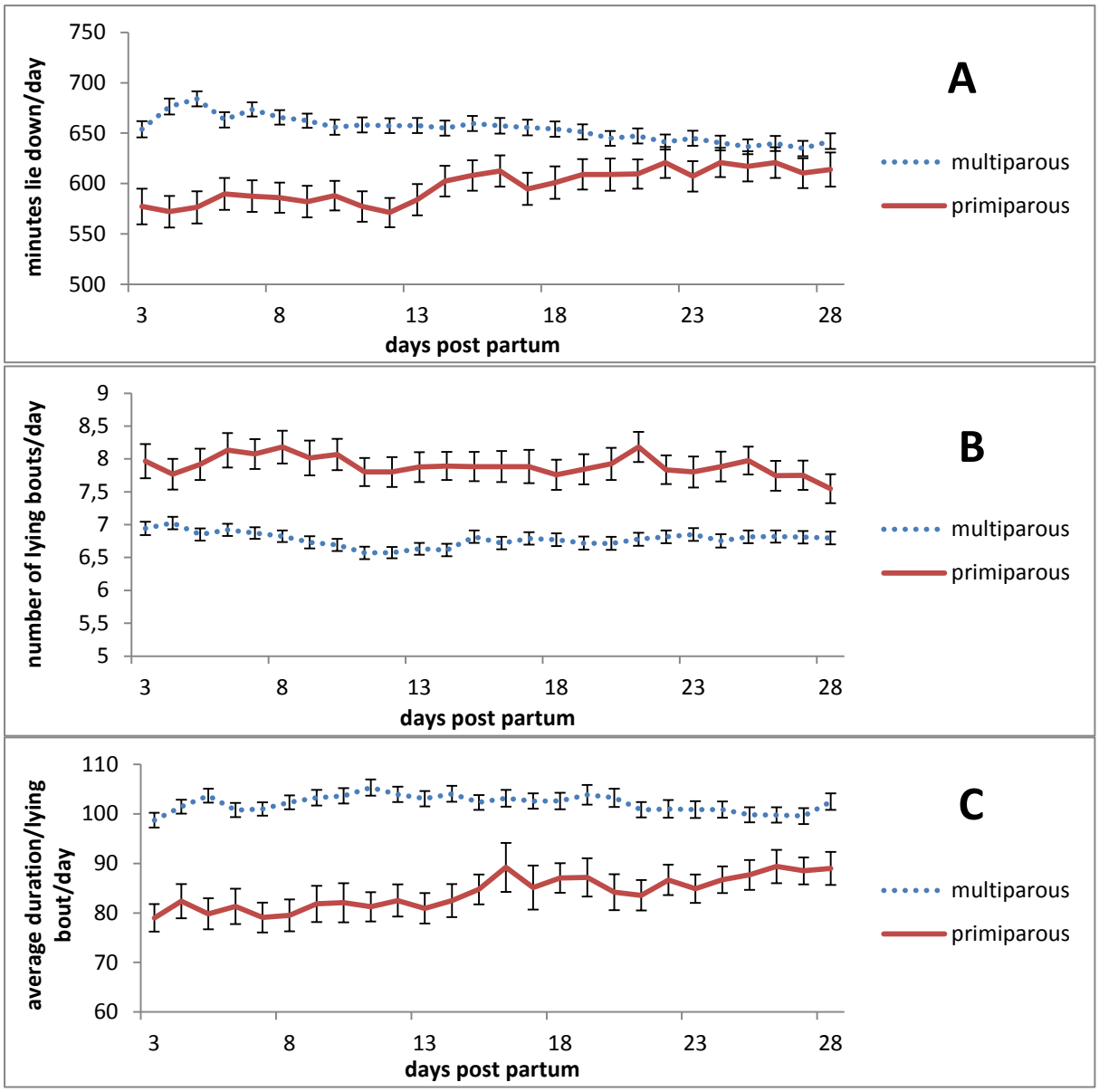

Figure 3. Changes on total lying time (A), the number of daily lying bouts (B), and the average lying bout duration (C) of primiparous and multiparous cows.

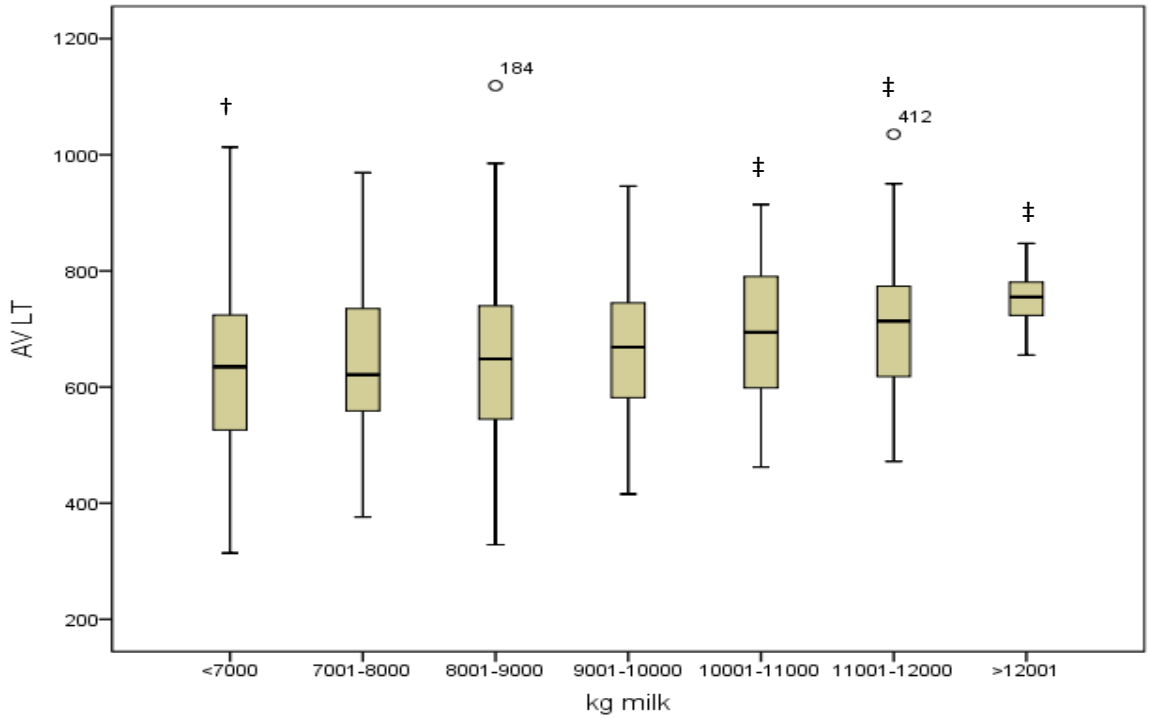

Figure 4. Relationship between lying time and milk production (in kg milk/305 days of production) days). Between †and ‡there is a significant difference (P=0,009).

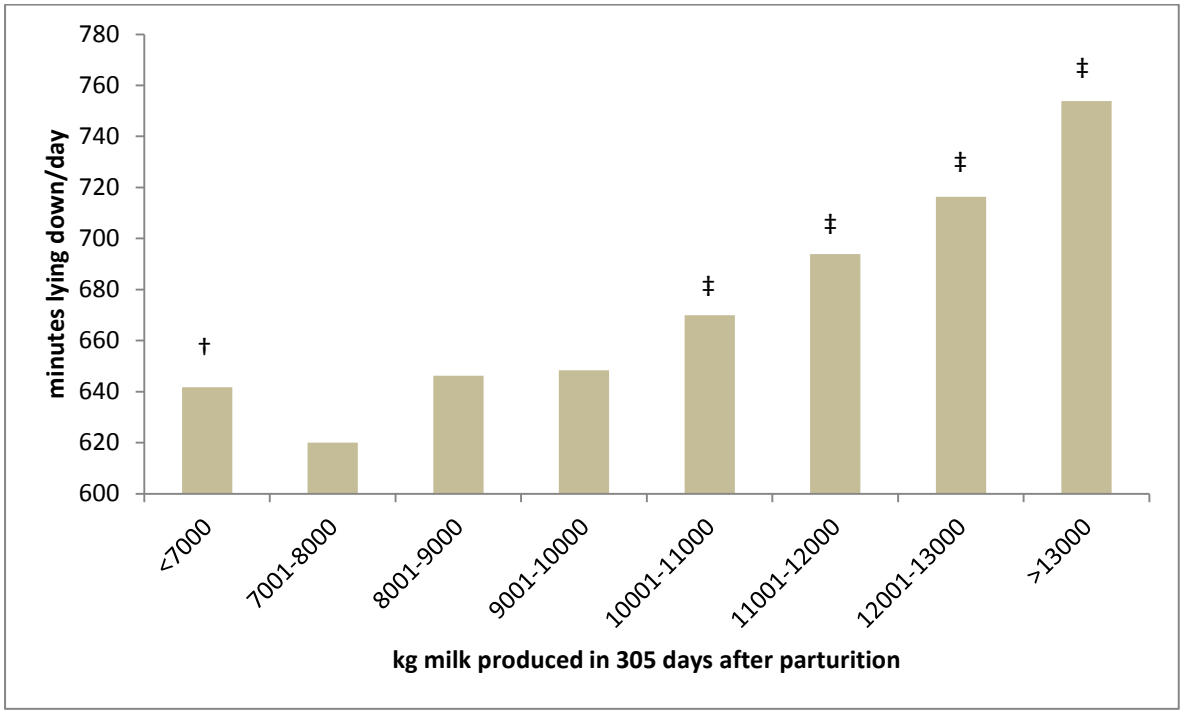

Figure 5. Average lying time per production group in minutes per day. Between † and ‡ there is a significant difference (P=0,009).

Discussion

Influence of bedding on lying times

This is not the first study that investigated the relationship between lying surface and lying times, However, outcomes differ between studies. The average lying times recorded in this study (663±8.6 and 611±8.8 min/day for cows housed on DB and MAT surfaces, respectively) were lower than values reported for dairy cows in other studies that investigated the influence of lying surface on lying times (Gomez, Cook 2010, Wechsler et al. 2000). These differences can be explained by the fact that those studies did not select on days in milk (DIM), whereby the mean DIM was 167 while is this study it is 16. Maselyne et al. (2017) explained the significance of DIM when interpreting data on lying behavior because daily lying time increased towards the end of lactation (Maselyne, Pastell et al. 2017). Nevertheless, the trend in lying times between DB and MAT are consistent with previous studies. It is concluded that DB herds cows spend more hours per day lying down compared with MAT herds (Calamari et al. 2009, Ito et al. 2014, Haley et al. 2000, Gomez, Cook 2010, von Keyserlingk, Barrientos et al. 2012). There is one study that concluded that MAT are equivalent to DB surfaces (Wechsler et al. 2000). There is not explained what the depth of the bedding is. For DB lying surface is the bedding depth of great importance, therefore this could be an explanation for the equal lying times (Tucker et al. 2009a).

In this study, cows housed on DB surfaces had fewer lying bouts of longer duration compared with cows housed on MAT(DB: 6.6±0.12 bouts of 107.2±2.00 minutes, MAT: 7.2±0.11 bouts of 91.8±1.81 minutes). This trend is comparable with other studies (Gomez, Cook 2010, Ito et al. 2014) and can be explained by the fact that cows divided their lying time in less periods of longer duration when the lying surface consist of better quality and provides more softness. Tucker et al.(2009) argued that a lying bout becomes uncomfortable when the lying bouts are longer than 80 minutes, and so cows may switch sides to alleviate this discomfort. However, the mean duration of a lying bout in this study is 10 to 25 minutes longer. This can be explained by the way of measuring the bout. In the study of Tucker et al. (2009), the bout duration is measured by using a continuous observation from video. In this study the bout duration is measured by 'Nedap smarttag leg' which sent every 15 minutes information to the ID-controller. The system knows how many minutes the cow had lie down in those 15 minutes, but does not know if the cow stood up for a while when the cow lies down for only 14 minutes or lie 14 minutes in one single bout. Therefore, the system counts a lying bout if there was a lying period for at least 15 minutes. If the time between a lying period and the next lying period is less than 15 minutes, both lying periods will be counted as one and the same lying bout. In this way, the system cannot count a single bout if the cow switched position.

Influence of milking system on lying times

This is not the first study that investigates lying times between dairy herds milked with an AMS or an MP. However, the results of the previous study were based upon data from before 2004 and it is well known that AMS have been improved in 14 years (Spolders et al. 2004). The average lying times found in this study were 657±13.8 min/day., 7,15±0,19 bouts/day of 97,7±1,4 minutes for AMS herds, and 637±6,8 min/day., 6,8±0,09 bouts/day of 102,4±3,5 minutes for MP herds per day. The study conducted by Spolders et al. (2004) reported different outcomes. They concluded that cows milked in an AMs had shorter lying times compared with cows milked in an MP.

AMS herds divided their lying time in more bouts of shorter duration compared with MP herds. This can be explained by the fact that a cow in the AMS herd decides herself when she wants to be milked. Cows milked by an AMS get 2,8 times a day milked (Stefanowska, Ipema et al. 1999). This implicates cows have to get up frequently and therefore have more lying bouts of shorter duration.

Figure 2A shows a dip in the graph at 10 days postpartum, but there is no substantiated explanation for this dip. All farms showed this dip, however with different severity ranging from 10 to 84 minutes shorter lying time compared to the day before. Combining the lying deprivation with the age of the cows, an interesting result is obtained. MC cows showed a larger dip compared with PC, with a difference between day 10 and day 9 of -33.47 minutes and -11.50 minutes, respectively. A possible explanation for this difference could be the fact that multiparous cows are more sensitive for post-partum disease (Lee, Kim 2006). However, research to the most common post-partum disease subclinical ketosis showed that cows with subclinical disease spent more time lying down(Kaufman, LeBlanc et al. 2016). Lame cows spent also more time lying down and prolonged the duration of their lying bouts(Ito, von Keyserlingk et al. 2010). Another possible explanation for the dip at day 10 could be a first silent heat, however, it takes 18 to 25 days after parturition before the first ovarian activity (Senger 2005, Stevenson, Call 1983). There is no substantiated explanation found for the dip in lying times in AMS herds on day 10 postpartum.

Furthermore, at the end of the graph there is hardly a difference in the lying times between AMS-herds and MP-herds (figure 2A). A reason for this could be the increasing numbers of milking's per day for the AMS-herds. At the top of lactation AMS-herds get milked more frequently compared with cows further in lactation(Ouweltjes 1998). If cows have more milking's per day, they have less time to lie down. To confirm this possible explanation, more research to lying times of AMS-herds and MP-herds is necessary, especially research to lying times over the whole lactation instead of only the first 28 days of the lactation.

Influence of parity on lying times

The relationship between parity and lying behavior is reported before (von Keyserlingk, Cunha et al. 2011, Sepúlveda-Varas et al. 2014, Bewley, Boyce et al. 2010). The outcome of the present study is comparable with the outcome of the study conducted by Sepúlveda-Veras et al. (2014). They reported shorter lying time(s) for PC compared with MC, and that PC divided their lying time in more bouts of shorter duration. However, the reported lying times differ from each other. Sepulveda-Veras et al. (2014) reported lying times of 7.5 and 8.5 h/day divided in 9.7 and 8.4 bouts of 50.8 and 63.4 minutes for PC and MC, respectively. The present study found lying times of 10.0 and 10.9 h/day divided in 7.9 and 6.8 bouts of 84.0 and 102.0 minutes for PC and MC, respectively. These difference are, according to Sepúlveda-Veras et al.(2014), consistent with previous studies for cows on pasture. Cows on pasture have less time to spend lying down, because the cows spend time with grazing and walking to the milking system.

PC increase their lying time with DIM (figure 3A), an outcome which was also found in a previous study (Sepúlveda-Varas et al. 2014, Vasseur, Rushen et al. 2012). The lying time increases over time postpartum, owing to the increased bout duration. The first week showed a difference of 90 minutes per day between MC and PC, while in the third week this was 24 minutes.

The shorter lying time for the PC could be due to the fact that those cows have more difficulties in coping with their new environment than MC. PC have to be active at less favored times and have to deal with less preferred places (González, Yabuta et al. 2003).

The present study investigated the first 28 days of the lactation, in this period time postpartum × parity was significant. Moreover, figure 3A shows that the difference in total lying time per day declines during days in milk. For this reason, it is recommended to investigate whether the difference in lying times between PC and MC is only present in the first weeks of lactation or through the whole lactation. Another study found a significant difference in mean bout duration over the whole lactation between PC and MC. They did not found any difference in lying times (Vasseur et al. 2012). Other studies gave as explanation that the effect of increasing lying times by increasing DIM is caused by a decreasing pressure on the udder (Vasseur et al. 2012, Maselyne et al. 2017). This assumption reinforces the fact that AMS-herds spent more time lying down, because they get milked frequently over a day.

Influence of production on lying time

Data were plotted on a boxplot, this is the best way to describe the results because not only the mean but also the variance and spread of the data is given. The outcome of this study is in line with previous studies about milk production and lying times (R. Grant 2012, R. J. Grant 2006). However, this study does not show clearly that cows who lie down more, give more milk. This is reported by Grant (2011), he calculated that there will be 1 to 1,6 kg per cow more milk whenever cow comfort is improved resulting in one more hour of resting. With this study can be concluded that high productive cows spent on average more time lying down compared with low productive cows. In combination with Grant (2011), can be concluded that when cows have a longer resting period, the milk production will improve.

In figure 4 is shown that there is a large amount of spread in the lying times of the cows. For example, cows who give 7000 kg milk or less lay down 300 to 1000 minutes a day. Due to this wide spread there is no significant difference between all production groups. Nevertheless, there is a trend clearly visible in the mean lying times, mean lying times increase when productivity increases (figure 5). The significant difference was between cows who gave 7000 kg milk or less and cows who gave 10.000 kg milk or more ($P<0.009$). Furthermore, this study measured only the lying times of the cows in the first 28 days of lactation. It is recommended to investigate whether the high productive cows have longer lying times over the whole lactation. Moreover, in this study production data of 426 cows were used. The reason for this relative small number of data, is because data has been extracted from the management system 2 years after measuring the lying times. Most of the milk production data were not available, because some cows were culled.

Previous studies suggest that the fact that high productive cows spent more time lying down is beneficial, due to reduced stress on feet, reduced lameness, increased blood flow to the mammary gland, increased feeding activity, and greater overall cow health (R. J. Grant 2006). This corresponds with the of lying times found in this study. According this study and previous studies, a good surface must provide softness, thermal comfort and sufficient grip to rise. Moreover, it has been reported that a lying surface that does not provide softness, grip and thermal comfort can induce stress (Fisher et al. 2002, Munksgaard, Simonsen 1996). Stress strongly alters milk yield and its composition

(Piccioli Cappelli, Maianti et al. 2005). Overall, these results suggest that a better lying surface improve the milk production by increasing lying times and decrease stress.

Conclusion

In conclusion, the results of this study highlight that cows spent more time lying down on deep bedded lying surfaces and divided this time in fewer bouts of longer duration compared with soft lying mattresses. When cows get milked with an AMS, they spent more time lying down and had slightly more lying bouts of longer duration compared with a MP. MC spent more time lying down, and divided their lying time in fewer bouts of longer duration compared with PC. The difference in lying times between PC and MC is narrowing over time. Moreover, in this study there is found that when cows spent more time lying down, they will have a higher milk production.

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