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An exploration into the sleep of workers on block-calving, pasture-based dairy farms

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ABSTRACT

The benefits of sufficient and high-quality sleep for people are well documented. Insufficient sleep increases the risk of accidents, injuries, and negative health implications for people. This is especially relevant for farmers because they work with large animals and machinery. Dairy farming often requires early start times and long days, particularly over the high-workload calving period in block-calving, pasture-based systems. However, there is little published data quantifying the sleep quantity and quality of farmers over this period. In this study, the sleep patterns of workers (n = 33) on 10 New Zealand dairy farms were measured for 90 d over the spring calving period using a sleep measuring device (Oura ring, Oura Health Ltd., Oulu, Finland). Total sleep time (TST) averaged 6 h 15 min, lower than the required 7 to 9 h for optimal wellbeing and cognitive functioning. The TST decreased over the calving period and was significantly correlated with both sleep start and wake times. Factors such as work start time, farm location, and role on farm influenced sleep quantity and quality. Further research is required to better understand sleep and its effect on dairy farmers, over both the calving period and the remaining months of the year.
Key words: dairy, block-calving, sleep

INTRODUCTION

The benefits of sufficient sleep for people have been widely researched. Sleep is necessary for healthy functioning and survival, and is as important as food and water (Worley, 2018). Adequate sleep enables people to be vigilant, alert, sustain attention, and consolidate memories (Babkoff et al., 1991; Karni et al., 1994; Minkel et al., 2012), as well as maintain physical and mental health (Neckelmann et al., 2007; Medic et al., 2017). Dairy farming is a demanding career that can require long work hours, early starts, limited time off, physical work, and high stress (Knook et al., 2023). These factors can affect sleep patterns; however, the effect of dairy farming on farmers' sleep has had little investigation.

The consequences of poor sleep for dairy farmers have the potential for significant implications, due to their daily interaction with large animals and machinery, as well as frequently isolated work contexts. The task of milking cows has a considerable influence on the start time and length of the working day on dairy farms. When walking the cows to and from the dairy platform and cleaning up after milking are included, a single milking event on pasture-based dairy farms averages 6 h (Bewsell et al., 2008; Deming et al., 2018; Edwards et al., 2020). However, this task may not be undertaken by a single person, and the time taken may significantly differ in accordance with herd size, technology use, and efficiency. Most pasture-based farms milk twice a day (**TAD**; Edwards et al., 2020; Eastwood et al., 2022). Cows that are milked TAD also need time between milkings to rest, eat, and replenish their milk supply. Consequently, farmers that milk TAD will often start early in the morning to allow for this break and ensure afternoon milkings do not go late into the evening. Milking TAD therefore contributes to long days and early starts that could affect sleep quantity and quality. Some farmers have reduced number of milkings (milking frequency) per day to allow greater work flexibility and less time spent milking. Approximately 10% of dairy farms in New Zealand (**NZ**) milk once a day (**OAD**) for the entire lactation (Edwards, 2019). Milking OAD allows the milking to occur at any point during the day, eliminating the need for early starts.

In NZ pasture-based dairy systems where cows are grazed outside, the lactation season is designed to match feed available through pasture growth. Calving occurs over approximately 10 wk in spring, known as "block

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The list of standard abbreviations for JDS is available at adsa.org/jds-abbreviations-24. Nonstandard abbreviations are available in the Notes.

Table 1. Characteristics of the dairy farms (n = 10) that participated in the study[1]

Variable	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8	Farm 9	Farm 10
Location	SSO	SSO	SSO	SSO	SSO	WC	WC	WC	WC	WC
Maximum number of cows milking	650	480	580	670	590	810	900	1,080	1,080	1,000
Number of staff participating in the study	4	4	3	4	3	2	3	5	2	3
Milking frequency	OAD	OAD	OAD	TAD	TAD	TAD	TAD	TAD	TAD	TAD
Earliest milking time	0630	0530	0500	0500	0500	0500	0500	0400	0400	0430
Planned start of calving 2021	Aug. 18	Aug. 10	Aug. 13	Aug. 5	Aug. 5	Jul. 26	Jul. 25	Jul. 28	Jul. 27	Jul. 28

[1]SSO = Southland/South Otago; WC = West Coast; OAD = once a day; TAD = twice a day.

calving." The amount of work and therefore labor required over this period is considerably higher than the rest of the year due to the tasks associated with the grazing and milking management of multiple herds with different requirements, along with calf and calving cow management (Deming et al., 2018; Hogan et al., 2022).

A small number of published studies have specifically investigated farmers' sleep, but only one has studied dairy farmers. This study did not use quantitative sleep metrics, however, only perceived sleep disturbance, with 25% reporting disturbed sleep (Botha and White, 2013). This study was self-reported over the entire lactation season and did not specify other farm metrics that may have influenced the result. Other farming studies mostly focused on the outcome of sleep loss, such as accidents (Spengler et al., 2004) and loss of balance (Siu et al., 2015), rather than the factors influencing sleep quantity. Because dairy farming combines long hours with physical activity, greater investigation into farmers' sleep is needed, rather than potential outcomes being extrapolated from other studies, largely conducted with office workers.

Several metrics may be used to assess sleep quality and quantity, including total sleep time (**TST**; Watson et al., 2015); sleep efficiency (**SE**), the percentage of time spent asleep once in bed (Miyata et al., 2013); sleep onset latency (**SOL**), and the time it takes to fall asleep (Berry and Wagner, 2015). Intrapersonal (**I**) differences, the difference between consecutive nights for one individual, can also be useful to assess sleep quality and quantity. More recently, heart rate (**HR**) measures during sleep, including lowest heart rate (**LHR**) and root mean squared of successive differences (**RMSSD**) between successive heart beats has been used to assess an individual's response to stress (Hall et al., 2004).

The objectives of this study were to first determine whether farmers working on block-calving, pasture-based dairy farms were getting sufficient sleep quantity and quality over the spring calving period; and, second, to identify how factors, including milking frequency, location, and role on farm, may affect sleep quantity and quality. We hypothesized that the high workload over the spring calving period would result in suboptimal sleep quality and quantity. Information from this novel study can be used to inform future studies assessing the effect of dairy farming on farm workers' sleep.

METHOD

Study Procedures and Participants

A longitudinal observation study was conducted using repeated measurements with 35 workers on dairy farms (n = 10) over a 90-d period between the 1st of August and 30th October 2021 in the South Island of NZ, which corresponds with the spring calving period. Human ethics approval was obtained for the study through the Lincoln University Human Ethics Committee (#2021–17). Participants worked on farms located in the West Coast (**WC**) or Southland/South Otago (**SSO**) regions of NZ and were using either a OAD or TAD milking frequency. These regions were selected due to their proximity to researchers, the likelihood of having farms with herds being milked OAD, and farms having multiple workers (e.g., farms milking at least 450 cows). This approach was taken to limit variation between farms, so farm could be used as an explanatory factor. Farms that met the above criteria were identified through professional networks. A sample size of 9 participants per group was deemed sufficient power (0.8) to detect a ±0.2 h difference in TST (with a presumed SD of 0.33) at 10 time points. Additional participants were added to account for attrition.

The lead author approached the farm managers of prospective farms 6 wk before the beginning of the study. Phone scripts and additional information were prepared in accordance with the human ethics approval. If the farm managers expressed an interest in the study, more information was sent to them about the purpose and methodology, and the phone numbers of their staff members who met the below criteria for participation were collected. Staff were then contacted, and they were provided with the same information as the managers if they expressed

Table 2. Descriptive statistics of the sleep metrics: TST, SE, SOL, LHR, RMSSD, and sleep start time and wake time, as well as the intrapersonal variation of the relevant metrics for the participants (n = 33) over the 90-d study period

Metric[1]	Median	Upper quartile	Lower quartile	SD
TST (h:min)	6:15	7:08	5:21	1:21
I-TST (min:s)	50:36	80:54	34:54	33:10
Efficiency (%)	86	81	90	6.24
I-Efficiency (%)	3.9	5.6	2.7	2.32
SOL (min:s)	8:30	15:00	4:30	10:27
LHR (bpm)	55	60	52	6.63
I-LHR (bpm)	2.4	3.8	1.6	1.77
RMSSD	45	56	31	17.27
Sleep start time	2150	2252	2101	1:28
Wake time	0501	0417	0612	1:30

[1]TST = total sleep time, I-TST = intrapersonal TST, I-efficiency = intrapersonal efficiency, SOL = sleep onset latency, LHR = lowest heart rate, I-LHR = intrapersonal LHR, bpm = beats per minute, RMSSD = root mean squared of successive differences of heartbeats.

interest. Potential participants were then contacted 5 d after the initial phone call to confirm whether they wished to take part in the study. Anonymity was afforded to all those approached for the study whether they chose to participate or not. The criteria for selecting participants were as follows: full-time dairy farmers, aged between 18 and 65, and had access to a smartphone and reliable internet for data access. Ten farms indicated their interest in the study and 35 participants were enrolled. Sixteen participants were located on 5 farms in the WC area, all of which milked TAD, and 19 participants on 5 farms in SSO, which consisted of 2 TAD farms and 3 OAD milking farms (Table 1). Of the 35 enrolled participants, one withdrew during the study, but allowed their data to be used up until the withdrawal date, and one had their data removed from the study, resulting in data from n = 33 participants being included in the analysis. Both individuals were from farm 2.

Measures and Assessment

The day before the study started, a member of the research team visited all interested participants, and a sleep and activity measuring device (Oura Ring, Oura Health Ltd., Oulu, Finland) was fitted to whichever finger the participant felt most comfortable with in line with the manufacturer's specifications at the time of the study, and the corresponding application was installed on their phone. The Pittsburgh sleep survey (Buysse et al., 1989) was completed by each participant to identify if there were any sleep concerns before the study commenced. No concerns were identified. Data captured by the devices included: HR, TST, SE, SOL, and sleep start and end times. The device used a combination of accelerometer, temperature sensor and pulse wave variability amplitude data in combination with machine learning models to calculate these variables (Moshe et al., 2021). There is a high level of agreement among these measurements by the ring with polysomnography, the gold standard of sleep measurement (de Zambotti et al., 2019). The RMSSD between successive heart beats was also calculated by the ring's software. The ring's data reportedly has a high level of agreement with the gold standard of heart rate variation, the electrocardiogram (Kinnunen et al., 2020).

Participants were requested to only wear the rings overnight once they had finished work and to remove them before commencing work the following day due to health and safety protocol on farms. If the ring was not worn for a period of 3 consecutive days, the participant was sent a reminder to wear it via mobile phone text message. Data captured by the ring overnight was uploaded, via Bluetooth, to the Oura smartphone application when opened by the participant in the morning.

Table 3. Significance (*P*-values) for model factors, including week, location, role, and milking frequency[1]

	P-value			
Metric[2]	Week	Location	Role	MF
TST	0.003	0.287	0.191	0.397
I-TST	0.709	0.093	0.086	0.358
Efficiency	0.754	0.155	0.881	0.956
I-Efficiency	0.640	0.029	0.488	0.587
SOL	0.934	0.542	0.888	0.298
LHR	0.708	0.073	0.085	0.695
I-LHR	0.032	<0.001	0.696	0.609
RMSSD	0.562	0.139	0.185	0.482
Sleep start time	<0.001	0.179	0.019	0.298
Wake time	<0.001	0.009	0.098	0.739

[1]Factors are defined as follows: week (n = 1–13), location (WC or SSO), role (manager or other worker), and milking frequency (MF; OAD or TAD).

[2]TST = total sleep time, I-TST = intrapersonal TST, I-efficiency = intrapersonal efficiency, SOL = sleep onset latency, LHR = lowest heart rate, I-LHR = intrapersonal LHR, RMSSD = root mean squared of successive differences of heartbeats, MF = milking frequency.

Table 4. Percentage variance from nested variance component analysis for MF (OAD or TAD); MF within farm (n = 10); MF within farm within position (manager or other worker); and MF within farm within position within participant (n = 33), as well as percentage error

	% Variance				
Metric	MF	MF:farm	MF:farm:position	MF:farm:position:participant[1]	Error
TST	0.00	5.97	0.00	57.0	36.9
I-TST	0.00	5.02	12.7	NA	82.3
Efficiency	0.00	3.51	0.00	61.3	35.2
I-Efficiency	3.21	0	20.5	NA	76.3
SOL	1.94	0.00	0.00	29.8	68.2
LHR	0.00	0.00	15.3	69.1	15.7
I-LHR	8.61	7.72	8.86	NA	74.8
RMSSD	0.00	0.00	0.00	85.9	14.1
Sleep start time	4.64	0.00	0.00	60.9	34.4
Wake time	5.83	2.99	2.90	19.5	68.7

[1]NA = not applicable. Intrapersonal values (I-) excluded participant variation in the model (NA) because the value itself is already a measure of intrapersonal variation.

At the end of the study a member of the project team converted the data into an anonymized dataset. Participants were also visited by the lead author to collect the rings and were asked for feedback regarding the study and their calving experience.

Statistical Analysis

First, data were summarized as raw means with SD to compare the observed metrics to the literature. Second, sleep data were analyzed using a repeated measures model (R Core Team, 2022). Due to the participants not wearing the ring every night, particularly at the start and end of the study, data was only removed from the study when less than 10% of the potential points per week were present, which resulted in the removal of <1% of the total data recorded. Participant was the experimental unit, with repeated measures through time using weekly means (n = 13 weeks). Fixed effects used in the model were location (WC or SSO), role (manager or other worker), milking frequency (OAD or TAD), and week. The model was weighted against the number of data points that contributed to the weekly average value to account for any bias due to participant variation in use of the ring. Significance was declared if $P < 0.05$ and a tendency if $P < 0.1$.

The LSM from the repeated measures model for TST, sleep start and wake time were plotted by week to identify the trend of the significant relationships. Linear regression (R Core Team, 2022) was used to identify the relationship between TST and sleep start time, along with TST and wake time. Results are presented as the mean (estimate) for the linear equation, along with the R^2 and *P*-value for the relationship.

Last, nested variance component analysis (R Core Team, 2022) was used over weekly participant averages for sleep quantity and quality metrics. Milking frequency (OAD or TAD) was nested inside farm (n = 10), inside position (manager; other worker) and, last, participant (n = 33). Percentage variance for each level of nesting was reported.

RESULTS

Sleep Quantity and Quality Metrics

Sleep quantity (TST) was low, with a median value of 6 h 15 min over the study period for all farmers (Table 2). Week had a significant negative effect on TST (Table 3; $P < 0.05$), along with I-LHR, sleep start time, and sleep wake time. There was no effect of milking frequency (OAD vs. TAD) on any of the sleep variables measured in the sampled population ($P > 0.05$; Table 3). Sleep metrics were strongly influenced by location, with greater I-efficiency (4.87% vs. 4.09% ± 0.45%, $P = 0.029$), I-TST (68 vs. 50 ± 7.0 min, $P = 0.093$), I-LHR (3.6 vs. 2.4 ± 0.45 beats per minute, $P < 0.001$), and earlier wake time (05:10 vs. 05:36 ± 00:15, $P = 0.009$) for WC compared with SSO, respectively. Role (manager or other worker) was also significant ($P < 0.1$) for I-TST and LHR, with other workers having greater values for both metrics, along with sleep starting later than for managers. Variance in all metrics was predominantly due to the participant (Table 4). Milking frequency accounted for a small amount of variation in sleep start and wake times (4.64%; 5.83%), with position causing variation in LHR (15.28%). Farm accounted for a small amount of variation in sleep efficiency (3.51%) and wake time (2.99%). Error, or natural variation, was large for SOL and wake time.

Sleep Metrics over Time

There were pronounced effects of week on TST and sleep start and wake times as the study progressed (Fig-

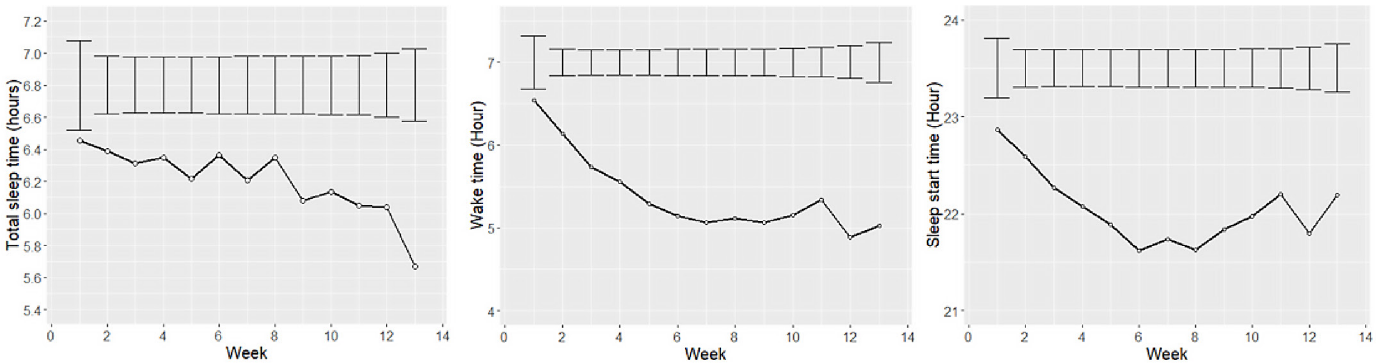

Figure 1. Weekly LSM for TST, wake time, and sleep start time over the spring calving period (n = 13 wk). Error bars indicate the standard error for weekly LSM.

ure 1). Total sleep time showed an overall negative trend over time, with a decrease in TST of approximately 0.8 h (or 48 min) between wk 1 and wk 13 (Figure 1). Sleep start time became earlier until wk 8. Wake time became earlier, decreasing by an hour and half from around 07:00 to 05:30 until wk 5, and then plateauing until the end of the study at wk 13 (Figure 1).

Relationship Between Sleep Metrics

The relationships between TST and sleep start time and wake time were investigated with linear regression. Both sleep start and wake time had a significant relationship with TST ($P < 0.001$; Figure 2). Total sleep time decreased with a later sleep start time and an earlier wake time. The data were variable, as demonstrated by the low R^2 values of 0.26 for sleep start and 0.28 for wake time.

DISCUSSION

The objective of this study was to assess whether block-calving, pasture-based dairy farmers were getting sufficient sleep quantity and quality over the spring calving period. We hypothesized that the increased workload over the spring calving period would result in suboptimal sleep quality and quantity. This hypothesis was partially supported by the results, which showed a low TST throughout calving; however, sleep quality measures were within normal values reported in the literature. The results also highlighted the influence of farm-management factors, such as start time, and the

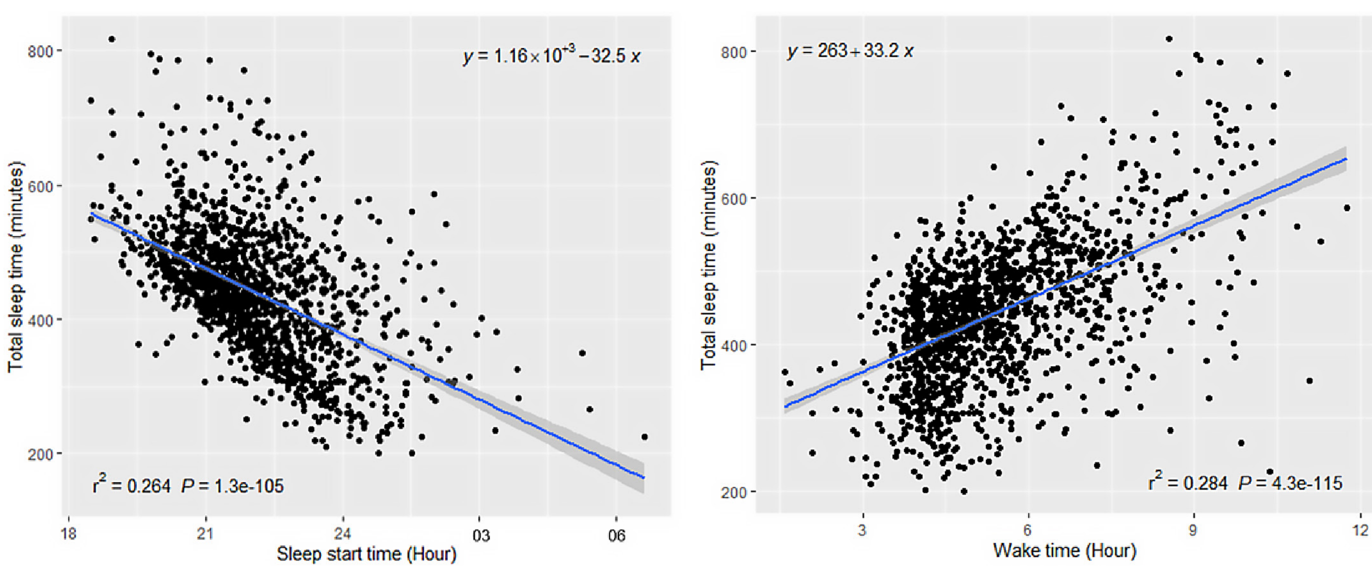

Figure 2. Linear regression of TST in minutes of all dairy farmer participants (n = 33) over the spring calving period (n = 90 d) by sleep start time and wake time (24-h clock). The shaded area around the line represents a 95% CI.

lack of influence of other farm-management factors, such as milking frequency, on sleep. This study was highly novel and highlights important results; however, due to the small sample size, greater than expected variation between individuals in sleep quantity and quality, and potentially confounding factors discussed below, further investigation into this topic and influencing factors is recommended.

Farmers in this study slept on average less than the recommended number of hours of sleep per day regardless of their milking frequency, geographical location, or role on farm. A sufficient amount of TST per day for healthy individuals ranges between 7 and 9 h (Watson et al., 2015). However, the average TST was just over 6 h for study participants. The large standard deviation indicates that some individuals were getting significantly less sleep on some nights, and then getting substantially more on other days. This indicates that these farmers were potentially experiencing "social jetlag" or a difference in sleep patterns between a "socially" determined day or workday, and a day off where sleep is more likely to be determined by circadian rhythm (Wittmann et al., 2006). A lack of sleep has been strongly associated with an increase in accidents (Gottlieb et al., 2018), serious errors (Landrigan et al., 2004) and a lowered perception of stress from cognitive demands (Minkel et al., 2012). Because dairy farming requires the use of heavy machinery and daily handling of large animals, accidents and errors have the potential to be serious.

Furthermore, numerous negative physiological effects on the individual are caused by a lack of sleep (Banks and Dinges, 2007). In particular, rapid eye movement (**REM**) sleep is not equally distributed between sleep cycles; the proportion of REM sleep increases with each sleep cycle (Walker, 2018). Therefore, when TST is suboptimal, the proportion of REM sleep that is sacrificed is larger than that of non-REM sleep. Rapid eye movement sleep is associated with emotional regulation and memory consolidation (Miller and Gehrman, 2019), which is particularly important to leadership, animal management, and learning on farm. More investigation into whether insufficient TST extends throughout the year, or whether farmers manage to compensate for this period of high workload and low TST elsewhere in the year, is justified, along with the inclusion of REM sleep measurements.

Total sleep time was correlated with sleep start and wake times (Figure 2). Total sleep time decreased when wake time, which we associated with work start time, was earlier. It also decreased when sleep started later. Wake time became earlier as calving progressed (Figure 1), presumably due to an increasing workload. Sleep start time also became earlier as calving progressed; however, even with participants going to bed earlier, it was still inadequate to offset earlier start times and TST continued to be insufficient. Despite an expectation that those milking OAD would be starting later and therefore this would correlate to increased TST compared with TAD farmers, the significant relationship between TST and sleep start and wake times was consistent for both milking frequencies. Both the Oura data and verbally collected feedback indicated that there was insufficient time between the end of work and starting again the following day for farmers to achieve sufficient TST, alongside other important activities such as cooking, eating, interaction with family, and a period of relaxation before bed. Some participants indicated that they were expected to check on calving cows in the evening, consequently bedtime was later than usual as they finished work later. Previous research has highlighted the importance of having this rest and relaxation time between work and bedtime as critical to good quality and enough sleep (O'Keefe and Gander, 2012). Therefore, ensuring a sufficient gap between work ending and starting again is important to ensuring optimal TST. This may entail adjusting rosters, better delegation, and prioritization of tasks, education on the role of sleep in human health, the integration of certain technology, or hiring additional workers. The addition of roster, technology use, task analysis, and detailed calving data should be included in future studies to further investigate the relationship between these factors and sleep.

The sleep quality metrics measured in this study, other than TST, were generally within an acceptable range. The percentage of time spent asleep when in bed (SE) was 85% with no significant effect for any model factors, indicating that sleep quality of the participants was adequate (Miyata et al., 2013). However, due to the low TST, an adequate SE would be expected, because tired individuals will usually fall asleep quickly. The time taken to fall asleep (SOL), was greater than 5 min so did not indicate severe fatigue. The SOL values were unexpected; due to the low TST value and physical nature of the work, increased fatigue was anticipated and therefore a lower SOL. Capturing activity data, along with alcohol and caffeine use would be recommended for future studies to assess the addition of these factors toward stress metrics. However, LHR values were high compared with another study (Waldeck and Lambert, 2003), with a value between 40 and 50 beats per minute being normal for healthy adults (Sleep Foundation, 2023). Stress, anxiety, and a later bedtime can increase sleeping heart rate (Azza et al., 2020, Faust et al., 2020). The HR variability measure RMSSD was also high compared with other studies (Macartney et al., 2022). A low RMSSD and a higher HR are linked, due to less time between heartbeats giving less time for variability. Overall, these trends indicate that farmers may be stressed over the spring period, but to what extent this contributes to TST is unclear.

There are many possible reasons for low value of TST in this study. First, we hypothesize that there is a lack of knowledge in agriculture around the effects of a lack of sleep. Sleep is acknowledged as an “expendable luxury” (Dzaja et al., 2005), as noted in previous studies of the general population. Even though it is as important as food and water, it is often prioritized the lowest out of the 3 (Worley, 2018). A common reason given for the low value of TST by participants in this study was the priority of other activities after work, including socializing, relaxing, cooking, and spending time with their families.

The lack of significant relationships between sleep quantity and quality metrics and milking frequency was likely due to the differences in management between the farms. When we classified farms as OAD or TAD this only considered one aspect of their management. Although we expected that OAD milking may allow for shorter working days, and therefore more sleep, this did not consider the other aspects of management on the farm. For the 3 OAD farms in this study one used the afternoon to work with their dry stock, another separately milked their newly calved cows in the afternoon, and the other managed the crop wintering of their dry cows, so afternoons were spent managing crop and dry cows during the calving period. The mixed enterprise work and crop wintering of dry cows were tasks that were not present on the TAD farms. Therefore, these OAD farms did not actually provide their workers with additional time to rest and relax in the afternoons, despite not milking during this time and smaller herd sizes. We also expected that milking OAD would allow for a later start time. However, these farms did not do this and were still requiring start times of around 0500 h (Table 1), which was comparable to the TAD farms of a similar size. This highlights the likely effect of farm management and work organization and that simply adopting a practice that could be beneficial to TST (e.g., OAD milking), may have a limited effect unless other changes (e.g., the timing of that milking or not adding additional farm work) are also made. However, due to the limited sample size (n = 11) of participants milking OAD, further investigation into the effect of milking frequency on farmers’ sleep is warranted to see if this hypothesized relationship exists within other OAD farm systems.

Role and location significantly ($P < 0.05$) affected sleep quality and HR measures. Role indicated that “other workers” had a higher LHR than managers and started sleep later. A potential reason for this could be that other staff were usually younger than managers and were perhaps prioritizing socializing over sleep. Location indicated that SSO farmers had a lower LHR and a later wake time. West Coast farmers noted that their spring rainfall had been particularly high the year of the study, resulting in unfavorable conditions for calving cows, and consequently work and stress increased. Conversely, SSO farmers reported favorable spring conditions. The WC is also more isolated from larger cities than SSO and consequently farmers can have greater difficulty recruiting staff; 4 of the 5 WC managers noted that their farms were understaffed over the study period, which could also have affected HR measures due to increased stress and workload. The WC farms were also milking more cows (Table 1) with an average herd size of 974 cows compared with 594 in SSO; therefore earlier wake times would have been required on days participants were milking.

Overall, the number of participants and farms (n = 33; n = 10, respectively), the frequency with which the ring was worn was a limitation of this study. The rings were worn, on average, for 57% of the study period by participants. Data were also not captured during daytime naps due to the health and safety concerns of wearing the ring throughout the working day. Spring calving is a period of high workload, so wearing the ring overnight was difficult to prioritize for some participants, despite daily reminders to wear it for those who were not; this also indicates the potential difficulty of capturing information in addition to the sleep data. Therefore, future studies should account for a low usage of measuring devices when calculating participant numbers, particularly if the study is over a period of high workload. This study also did not balance participants for metrics such as body weight (Gonnissen et al., 2013) and gender (Bei et al., 2015), which affect sleep quantity and quality, because of the challenge recruiting participants. The discrepancy between herd sizes between milking frequency and locations was also a limitation; however, this was a consequence of using commercial farms rather than a controlled research setting. As much time as possible should be given to recruit participants and farms to enable results to be as balanced as possible. Rosters and hours worked were also not factored in due to a lack of reliably recorded data, so providing an integrated platform for recording would also be recommended for future studies. However, this study and the methodology were novel, and the results provide an important insight into dairy farmers’ sleep. The results indicate that there is potential for more relationships to be investigated about farmers’ sleep and wellbeing, both over high-workload periods and throughout the year.

CONCLUSIONS

People working on block-calving, pasture-based dairy farms had insufficient sleep over the spring calving period. Total sleep time was correlated with sleep start and wake times and decreased throughout spring as workloads increased. Milking frequency did not affect sleep quantity or quality metrics in this study; however, this may have been influenced by the small sample size. Other factors, such as the participant's role on farm and the location of the farm, did affect intravariability in TST, LHR, and SE, along with wake time. Insufficient time between work finish and work starting the following day to allow for optimal TST and other important activities is hypothesized to also have adversely affected sleep quantity. Heart rate measures indicated that farmers are likely to be physiologically stressed over this period.

NOTES

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Nonstandard abbreviations used: HR = heart rate; I = intrapersonal; LHR = lowest heart rate; MF = milking frequency; OAD = once a day; REM = rapid eye movement; RMSSD = root mean squared of successive differences (between successive heartbeats); SE = sleep efficiency; SOL = sleep onset latency; SSO = Southland/South Otago regions of NZ; TAD = twice a day; TST = total sleep time; WC = West Coast region of NZ; NZ = New Zealand.

REFERENCES

Azza, Y., M. Grueschow, W. Karlen, E. Seifritz, and B. Kleim. 2020. How stress affects sleep and mental health: Nocturnal heart rate increases during prolonged stress and interacts with childhood trauma exposure to predict anxiety. Sleep 43:zsz310. https://doi.org/10.1093/sleep/zsz310.

Babkoff, H., T. Caspy, Y. Hishikawa, and M. Mikulincer. 1991. Subjective sleepiness ratings: The effects of sleep deprivation, circadian rhythmicity and cognitive performance. Sleep 14:534–539. https://doi.org/10.1093/sleep/14.6.534.

Banks, S., and D. F. Dinges. 2007. Behavioral and physiological consequences of sleep restriction. J. Clin. Sleep Med. 3:519–528. https://doi.org/10.5664/jcsm.26918.

Bei, B., S. Coo, F. C. Baker, and J. Trinder. 2015. Sleep in women: A review. Aust. Psychol. 50:14–24. https://doi.org/10.1111/ap.12095.

Berry, R. B., and M. H. Wagner. 2015. Subjective and objective measures of sleepiness. Pages 181–187 in Sleep Medicine Pearls. 3rd ed. R. B. Berry and M. H. Wagner, ed. W.B. Saunders, Philadelphia.

Bewsell, D., D. A. Clark, and D. E. Dalley. 2008. Understanding motivations to adopt once-a-day milking amongst New Zealand dairy farmers. J. Agric. Educ. Ext. 14:69–80. https://doi.org/10.1080/13892240701820611.

Botha, N., and T. White. 2013. Distress and burnout among NZ dairy farmers: Research findings and policy recommendations. Ext. Farming Syst. J. 9:160–170.

Buysse, D. J., C. F. Reynolds III, T. H. Monk, S. R. Berman, and D. J. Kupfer. 1989. The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. Psychiatry Res. 28:193–213. https://doi.org/10.1016/0165-1781(89)90047-4.

de Zambotti, M., L. Rosas, I. M. Colrain, and F. C. Baker. 2019. The sleep of the ring: Comparison of the ŌURA sleep tracker against polysomnography. Behav. Sleep Med. 17:124–136. https://doi.org/10.1080/15402002.2017.1300587.

Deming, J., D. Gleeson, T. O'Dwyer, J. Kinsella, and B. O'Brien. 2018. Measuring labor input on pasture-based dairy farms using a smartphone. J. Dairy Sci. 101:9527–9543. https://doi.org/10.3168/jds.2017-14288.

Dzaja, A., S. Arber, J. Hislop, M. Kerkhofs, C. Kopp, T. Pollmächer, P. Polo-Kantola, D. J. Skene, P. Stenuit, I. Tobler, and T. Porkka-Heiskanen. 2005. Women's sleep in health and disease. J. Psychiatr. Res. 39:55–76. https://doi.org/10.1016/j.jpsychires.2004.05.008.

Eastwood, C. R., J. P. Edwards, and V. Bates. 2022. Science communication and engagement in adaptive farm-systems research: A case study of flexible milking research in New Zealand. Anim. Prod. Sci. 64:1–12. https://doi.org/10.1071/AN22358.

Edwards, J. P. 2019. Comparison of milk production and herd characteristics in New Zealand herds milked once or twice a day. Anim. Prod. Sci. 59:570–580. https://doi.org/10.1071/AN17484.

Edwards, J. P., B. Kuhn-Sherlock, B. T. Dela Rue, and C. R. Eastwood. 2020. *Short communication:* Technologies and milking practices that reduce hours of work and increase flexibility through milking efficiency in pasture-based dairy farm systems. J. Dairy Sci. 103:7172–7179. https://doi.org/10.3168/jds.2019-17941.

Faust, L., K. Feldman, S. M. Mattingly, D. Hachen, and N. V. Chawla. 2020. Deviations from normal bedtimes are associated with short-term increases in resting heart rate. NPJ Digit. Med. 3:39. https://doi.org/10.1038/s41746-020-0250-6.

Gonnissen, H. K. J., T. C. Adam, R. Hursel, F. Rutters, S. P. M. Verhoef, and M. S. Westerterp-Plantenga. 2013. Sleep duration, sleep quality and body weight: Parallel developments. Physiol. Behav. 121:112–116. https://doi.org/10.1016/j.physbeh.2013.04.007.

Gottlieb, D. J., J. M. Ellenbogen, M. T. Bianchi, and C. A. Czeisler. 2018. Sleep deficiency and motor vehicle crash risk in the general population: A prospective cohort study. BMC Med. 16:44. https://doi.org/10.1186/s12916-018-1025-7.

Hall, M., R. Vasko, D. Buysse, H. Ombao, Q. Chen, J. D. Cashmere, D. Kupfer, and J. F. Thayer. 2004. Acute stress affects heart rate variability during sleep. Psychosom. Med. 66:56–62. https://doi.org/10.1097/01.PSY.0000106884.58744.09.

Hogan, C., J. Kinsella, B. O'Brien, A. Markey, and M. Beecher. 2022. Estimating the effect of different work practices and technologies on labor efficiency within pasture-based dairy systems. J. Dairy Sci. 105:5109–5123. https://doi.org/10.3168/jds.2021-21216.

Karni, A., D. Tanne, B. S. Rubenstein, J. J. Askenasy, and D. Sagi. 1994. Dependence on REM sleep of overnight improvement of a perceptual skill. Science 265:679–682. https://doi.org/10.1126/science.8036518.

Kinnunen, H., A. Rantanen, T. Kenttä, and H. Koskimäki. 2020. Feasible assessment of recovery and cardiovascular health: Accuracy of nocturnal HR and HRV assessed via ring PPG in comparison to medical grade ECG. Physiol. Meas. 41:04NT01. https://doi.org/10.1088/1361-6579/ab840a.

Knook, J., C. Eastwood, K. Mitchelmore, and A. Barker. 2023. Wellbeing, environmental sustainability and profitability: Including plurality of logics in participatory extension programmes for enhanced farmer resilience. Sociol. Ruralis 63(Suppl. 1):141–162. https://doi.org/10.1111/soru.12413.

Landrigan, C. P., J. M. Rothschild, J. W. Cronin, R. Kaushal, E. Burdick, J. T. Katz, C. M. Lilly, P. H. Stone, S. W. Lockley, D. W. Bates, and C. A. Czeisler. 2004. Effect of reducing interns' work hours on serious medical errors in intensive care units. N. Engl. J. Med. 351:1838–1848. https://doi.org/10.1056/NEJMoa041406.

Macartney, M. J., P. Larsen, N. Gibson, S. Michael, J. Drain, G. E. Peoples, and H. Groeller. 2022. Overnight sleeping heart rate variability of Army recruits during a 12-week basic military training course. Eur. J. Appl. Physiol. 122:2135–2144. https://doi.org/10.1007/s00421-022-04987-3.

Medic, G., M. Wille, and M. E. Hemels. 2017. Short- and long-term health consequences of sleep disruption. Nat. Sci. Sleep 9:151–161. https://doi.org/10.2147/NSS.S134864.

Miller, K. E., and P. R. Gehrman. 2019. REM sleep: What is it good for? Curr. Biol. 29:R806–R807. https://doi.org/10.1016/j.cub.2019.06.074.

Minkel, J. D., S. Banks, O. Htaik, M. C. Moreta, C. W. Jones, E. L. McGlinchey, N. S. Simpson, and D. F. Dinges. 2012. Sleep deprivation and stressors: Evidence for elevated negative affect in response to mild stressors when sleep deprived. Emotion 12:1015–1020. https://doi.org/10.1037/a0026871.

Miyata, S., A. Noda, K. Iwamoto, N. Kawano, M. Okuda, and N. Ozaki. 2013. Poor sleep quality impairs cognitive performance in older adults. J. Sleep Res. 22:535–541. https://doi.org/10.1111/jsr.12054.

Moshe, I., Y. Terhorst, K. Opoku Asare, L. B. Sander, D. Ferreira, H. Baumeister, D. C. Mohr, and L. Pulkki-Råback. 2021. Predicting symptoms of depression and anxiety using smartphone and wearable data. Front. Psychiatry 12:625247. https://doi.org/10.3389/fpsyt.2021.625247.

Neckelmann, D., A. Mykletun, and A. A. Dahl. 2007. Chronic insomnia as a risk factor for developing anxiety and depression. Sleep 30:873–880. https://doi.org/10.1093/sleep/30.7.873.

O'Keefe, K., and P. Gander. 2012. Best practice rostering, shift work and hours of work for resident doctors: A review. Massey University Sleep/Wake Research Centre, Massey University, Wellington, New Zealand. Accessed Feb. 24, 2022. https://www.apex.org.nz/wp-content/uploads/Literature-review-Best-practise-rostering-FINAL.pdf.

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. Accessed Apr. 2, 2023. http://www.R-project.org.

Siu, K.-C., C.-K. Huang, M. Beacom, S. Bista, and R. Rautiainen. 2015. The association of sleep loss and balance stability in farmers. J. Agromedicine 20:327–331. https://doi.org/10.1080/1059924X.2015.1042615.

Sleep Foundation. 2023. What is a normal sleeping heart rate? Accessed Oct. 1. 2023. https://www.sleepfoundation.org/physical-health/sleeping-heart-rate.

Spengler, S. E., S. R. Browning, and D. B. Reed. 2004. Sleep deprivation and injuries in part-time Kentucky farmers: Impact of self reported sleep habits and sleep problems on injury risk. AAOHN J. 52:373–382. https://doi.org/10.1177/216507990405200905.

Waldeck, M. R., and M. I. Lambert. 2003. Heart rate during sleep: Implications for monitoring training status. J. Sports Sci. Med. 2:133–138.

Walker, M. 2018. Why We Sleep: The New Science of Sleep and Dreams. Penguin Books, Harlow, England.

Watson, N. F., M. S. Badr, G. Belenky, D. L. Bliwise, O. M. Buxton, D. Buysse, D. F. Dinges, J. Gangwisch, M. A. Grandner, C. Kushida, R. K. Malhotra, J. L. Martin, S. R. Patel, S. F. Quan, and E. Tasali. 2015. Recommended amount of sleep for a healthy adult: A joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society. Sleep 38:843–844. https://doi.org/10.5665/sleep.4716.

Wittmann, M., J. Dinich, M. Merrow, and T. Roenneberg. 2006. Social jetlag: Misalignment of biological and social time. Chronobiol. Int. 23:497–509. https://doi.org/10.1080/07420520500545979.

Worley, S. L. 2018. The extraordinary importance of sleep: The detrimental effects of inadequate sleep on health and public safety drive an explosion of sleep research. P T. 43:758–763.

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