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The Association of Sleep Loss and Balance Stability in Farmers

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ABSTRACT. Sleep deprivation has been linked to injuries, illnesses, and reduced performance measures. Yet, it is unclear how sleep loss contributes to the high rates of injuries and falls in agriculture. In this study, the authors evaluated sleep loss and quantified its association with balance in five farmers, who wore an ActiWatch to record their sleeping patterns in six repeated weekly observation periods. Acute sleep loss was computed as the net sleep (sleeping hours the night before balance testing − average sleep hours during the week). All farmers performed four balance tests on either one foot or both feet and with eyes open or closed. Balance was measured using a pressure mat to monitor the change in center of pressure (CoP) of the feet in anteroposterior (AP) and mediolateral (ML) directions. Spearman's rank correlation coefficient indicated balance outcomes were strongly and negatively correlated with the net sleep ($P < .05$). As the net sleep decreased, farmers became less stable, particularly indicated by an increase in the area, total displacement, and deviations of CoP in both AP and ML directions while standing on both feet with eyes open. Fisher's exact test showed an association between the CoP in AP direction and the net sleep ($P = .020$, odds ratio [OR] = 7.37). Thus, the odds of having reduced balance stability were 7.4 times higher when farmers slept less than their average hours during the night prior to the balance test. These results suggest that acute sleep loss impacts balance stability that may lead to falls. Understanding the association of sleep loss and balance stability is important in prevention of agricultural injuries.

KEYWORDS. Falls, injury, sleep deprivation

INTRODUCTION

Working hours in agriculture are variable and dependent on the season and weather. Spring planting and fall harvest times can involve extremely long workdays when the weather is favorable. Farm injuries are most frequent during spring, summer, and fall.[1] The seasonal variation is even stronger for minor injuries than for serious injuries.[2] In Saskatchewan, farm owner-operators' average weekly work hours were 70 hours in spring, 60 hours in

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summer, 70 hours in fall, and 28 hours in winter.[3] Operators of large farms are exposed to extended workdays during peak seasons. Harvest time may continue several weeks with very limited sleeping hours.

The peak seasons in crop production for part-time farmers are similar to those for full-time farmers. Part-time farmers may work off the farm during daytime and complete their farm work during evenings and weekends. This may result in a seasonal overload and accumulating significant sleep deprivation. Although there is very little information on farmers' working hours on and off the farm, it is evident from the continued high injury rates, increasing farm sizes, and increasing reliance on off-farm employment that sleep deprivation is a major problem among farmers.[4–6] We addressed this gap in knowledge by documenting sleep hours and balance performance in a sample of farmers, and identifying the association of acute sleep loss and balance stability. We hypothesized that sleep loss would negatively affect balance stability in farmers, which may be a contributing factor to their high injury rates during peak seasons.

METHODS

A convenience sample of eight male farmers (aged 54 ± 10) was enrolled among clients of a medical clinic in Fremont, Nebraska. They signed the consent form in the first session. They filled a questionnaire to self-report their basic demographics, farm characteristics, and typical hours of sleep and work. They completed medical screening, having no health conditions that could affect their participation in the study. Their balance was measured using a pressure-mapping mat (MatScan; Tekscan, Boston, MA) that quantifies contact pressure distribution (center of pressure [CoP]) for both feet. Participants stood on the mat on one leg (right) or both legs with eyes open or eyes closed for 10 seconds. Each condition was tested three times for a total of 18 trials. The CoP was recorded to compute the area, total displacement, and deviations of CoP in anteroposterior (AP) and mediolateral (ML) directions (Table 1).

Participants also wore an ActiWatch (Philips Healthcare, Andover, MA) for a week to record their daily activity and sleep hours. Acute sleep loss was computed as the net sleep = sleeping hours the night before balance testing − average sleeping hours during previous week. Thus, the net sleep (measured in hours) was negative when the participants slept less than their average weekly sleep hours during the observation week, and positive when they slept longer than average. Participants returned the ActiWatch for data analysis in the session at the end of each week. Same questionnaire and balance assessment was performed in the beginning and end of each observation week. Overall, each participant completed six observation weeks: before, during, and after one planting and one harvest season.

We analyzed the net sleep and quantified its association with balance measures using the Spearman's rank correlation coefficient in SPSS, version 22 (IBM Corp., Armonk, NY). We then categorized the net sleep and balance measures into good or poor and evaluated the association (odd ratios) between the two measures using the Fisher's exact test. The alpha level was set at .05.

RESULTS

Three out of eight participants did not complete the entire study due to various reasons, e.g., lost contact, unable to participate, too busy, etc. Only five participants were used for statistical analyses. Table 1 summarizes all balance measures in four conditions.

In Table 2, all balance measures were strongly and negatively correlated with the net sleep when farmers stood on both legs with eyes open. As the net sleep decreased (more negative), farmers became less stable, particularly indicated by an increase in the total area, total displacement of CoP, and the deviations of CoP in both AP and ML directions. Two balance measures (the total area of CoP and the deviation of CoP in ML direction) were moderate and

TABLE 1. Balance Measures in Four Conditions

Measure	Standing on the right leg				Standing on both legs			
	Eyes closed		Eyes open		Eyes closed		Eyes open	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
AREA	6.969	5.089	4.438	2.213	2.830	1.374	2.844	1.598
DISP	84.061	48.937	91.272	45.000	32.884	15.803	27.672	10.886
AP	5.001	1.778	3.590	0.976	3.453	1.281	3.247	1.188
ML	2.675	0.812	2.632	0.569	1.702	0.726	1.681	0.650

Note. AREA = the total area of center of pressure (CoP) in square centimeters (cm^2); DISP = the total displacement of CoP in cm; AP = the deviation of CoP in the anteroposterior direction in cm; ML = the deviation of CoP in the mediolateral direction in cm.

TABLE 2. Association Between Net Sleep* and Balance Measures

Measure	Standing on the right leg				Standing on both legs			
	Eyes closed		Eyes open		Eyes closed		Eyes open	
	ρ	*P* value	ρ	*P* value	ρ	*P* value	ρ	*P* value
AREA	.000	1.000	−.294	.222	−.464	.045	−.457	.049
DISP	−.395	.094	−.567	.011	−.414	.078	−.687	.001
AP	−.101	.681	−.249	.304	−.196	.421	−.551	.014
ML	.140	.569	−.052	.831	−.478	.039	−.595	.007

Note. AREA = the total area of center of pressure (CoP); DISP = the total displacement of CoP; AP = the deviation of CoP in the anteroposterior direction; ML = the deviation of CoP in the mediolateral direction.
*Net sleep = sleep hours during night prior to balance test − average weekly sleep hours.

negatively correlated with the net sleep while standing on both legs with eyes closed. Only total displacement of CoP was negatively correlated with the net sleep when farmers stood on the right leg with eyes open. No significant association was found between net sleep and balance measures while standing on the right leg with eyes closed.

In Table 3, Fisher's exact test revealed the deviation of CoP in AP direction was significantly associated with the net sleep when farmers stood on both legs with eyes open (odds ratio [OR] = 7.37, $P = .020$).

DISCUSSION

Our results support the hypothesis that acute sleep loss affects balance performance negatively. Increased acute sleep loss (negative net sleep) was associated with less stable balance (greater deviations of CoP) in farmers while standing on both feet with eyes open. Sleep deprivation might reduce the ability to pay attention and process sensory information (vision, vestibular, and somatosensory) to maintain balance.[7] When our participants slept less than their average weekly sleeping hours, their ability to maintain balance was compromised. The balance stability was affected more with eyes open than eyes closed, which could be due to the reduced ability to process more sensory information. Sleep deprivation may have lesser effect on balance when there is less sensory information to process, with eyes closed.

Consistent with the growing literature from laboratory-based research focused on the relationship between sleep deprivation and balance in general population,[8–12] we observed a strong association between acute sleep loss and balance stability in our small cohort of farmers. Compared with sleeping longer than their average weekly hours, the odds of having reduced balance stability (both feet on the

TABLE 3. Contingency Between Net Sleep and Balance Measures

Measure	Standing on the right leg				Standing on both legs			
	Eyes closed		Eyes open		Eyes closed		Eyes open	
	OR	*P* value	OR	*P* value	OR	*P* value	OR	*P* value
AREA	0.012	1.000	2.356	0.485	0.223	1.000	1.281	0.370
DISP	0.853	0.633	5.415	0.059	1.281	0.370	4.399	0.070
AP	0.121	1.000	0.121	1.000	0.223	1.000	7.368	0.020
ML	0.544	0.650	0.121	1.000	0.853	0.633	4.399	0.070

OR = odds ratio; AREA = the total area of center of pressure (CoP); DISP = the total displacement of CoP; AP = the deviation of CoP in the anteroposterior direction; ML = the deviation of CoP in the mediolateral direction.

ground) were 7.4 times higher when our farmers slept less than their average weekly hours the night before the balance test. The association of balance and acute sleep loss was surprisingly strong, considering that we did not see extremely long periods of wakefulness. At a minimum, all farmers had at least 5 hours of night sleep. The direct association of sleep deprivation and injury in agriculture would require further research. One study reported that adolescent youth on farms were 2 to 3 times more likely to get injured if they slept less than 9.25 hours on school nights or weekends.[13]

Numerous studies have addressed the effects of sleep deprivation in shift work and other employment situations.[14–17] Regulations have been developed for operating hours in transportation industries to reduce the negative effects of sleep deprivation on safety.[18,19] However, no similar studies, regulations, or guidance is available for self-employed farmers. Further studies with greater sample sizes would be beneficial to confirm the associations of sleep loss, balance stability, and injury in farmers and other self-employed workers who control their own working and sleeping hours. In this study, we focused on acute sleep loss during the night prior to the balance test. The effects of chronic sleep deprivation should be studied in farmers. Contrary to our expectation, we did not observe situations where farmers would work for days with only few hours of sleep during planting and harvest times. However, such situations do likely occur, and future research should involve sampling techniques to include high-risk farming populations. Overall, understanding the association between sleep loss and balance stability could be critical in developing new approaches for prevention of agricultural injuries.

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