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Sleep disturbances and disability following work-related injury and illness: Examining longitudinal relationships across three follow-up waves

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Summary

Despite the high burden of sleep disturbances among the general population, there is limited information on prevalence and impact of poor sleep among injured workers. This study: (a) estimated the prevalence of sleep disturbance following work-related injury; and (b) examined the longitudinal association between sleep disturbances and disability/functioning, accounting for reciprocal relationships and mental illness. Longitudinal survey data were collected from workers' compensation claimants with a time-loss claim in Victoria, Australia (*N* = 700). Surveys were conducted at baseline, 6 months and 12 months. Sleep disturbance was measured using the Patient-Reported Outcomes Measurement Information System (PROMIS) questionnaire. Disability/functioning was based on self-reported activity limitations, participation restrictions and emotional functioning. Path models examined the association between disability/functioning and sleep. Mean sleep disturbance *T*-scores were 55.2 (*SD* 11.4) at 6 months, with 36.4% of the sample having a *T*-score of 60+. Longitudinal relationships were observed between disability (specifically, emotional functioning) and sleep disturbances across successive follow-up waves. For example, each unit increase in T2 emotional functioning (five-point scale) was associated with a 1.1 unit increase in T3 sleep disturbance (approximately 29–76 scale). Cross-lagged path models found evidence of a reciprocal relationship between disability and sleep, although adjustment for mental illness attenuated the estimates to the null. In conclusion, sleep disturbances are common among workers' compensation claimants with work injuries/illnesses. Given the links between some dimensions of disability, mental health and sleep disturbances, the findings have implications for the development of interventions that target the high prevalence of sleep problems among working populations.

KEYWORDS

cross-lagged path model, disability, longitudinal, sleep disturbances, work injury

1 | INTRODUCTION

Sleep-related problems are common among general working populations. In Australia, prevalence estimates for sleep problems ranged from 33% to 49% of the general population in 2016 (Adams et al., 2017), with 16% of working adults reporting sleep difficulties or daytime sleep-related symptoms. In Canada, the prevalence of having at least one symptom of insomnia reached 40% of the general population in 2000 (Morin et al., 2011), with 13% of workers meeting the full diagnostic criteria for insomnia. In the USA, 2004–2007 prevalence estimates for short sleep duration (< 7 hr per day) among employed adults ranged from 23.1% to 40.5% across various industries (Luckhaupt, Tak, & Calvert, 2010). Studies of clinical patients also suggest that sleep problems may be worse among those with work-related versus non-work-related injuries (Solbach et al., 2018), as well as among those seeking or receiving workers' compensation benefits (Deyo et al., 2016).

Sleep problems may relate to poor sleep quality (e.g. difficulties falling or staying asleep), poor quantity (e.g. reduced time spent in a sleeping state) or excessive daytime sleepiness as a result of sleep problems (Alvaro et al., 2013; Litwiller, Snyder, Taylor, & Steele, 2017). Among working populations, sleep disturbances have been linked with various work and health outcomes, including an increased risk of work-related injury, delayed recovery following injury and greater healthcare expenditures (Hui & Grandner, 2015; Litwiller et al., 2017; Salminen et al., 2010; Salo et al., 2010). Thus, the high prevalence of sleep problems among workers represents a substantial public and occupational health concern. Sleep disturbances also are of policy interest given the role of sleep as a modifiable risk factor that transmits the effects of individual and organizational antecedents to subsequent work-related health and functioning (Hale, 2010; Litwiller et al., 2017; Magnusson Hanson, Chungkham, Åkerstedt, & Westerlund, 2014). However, despite the high burden of sleep disturbances and relevance to worker health (Litwiller et al., 2017; Magnavita & Garbarino, 2017), there is limited information on the prevalence and impact of sleep disturbances within the context of workers' compensation populations with a work-related injury/illness.

Previous research has found a link between sleep disturbances and disability (Buxton et al., 2012; Gradinger et al., 2011; Hui & Grandner, 2015; Linder, Jansen, Ekholm, & Ekholm, 2014; Litwiller et al., 2017; Magnavita & Garbarino, 2017; Vitkova et al., 2018). A 2014 cross-sectional study of Swedish workers on long-term sick leave (Linder et al., 2014) found that moderate to severe sleep disturbances were associated with difficulties in performing daily activities (e.g. making decisions, ability to concentrate and performing tasks) and worse psychological functioning (e.g. fatigability, sadness and pessimistic thoughts). A 2013 cross-sectional study of Dutch employees (Van Mill, Vogelzangs, Hoogendijk, & Penninx, 2013) found that insomnia and short sleep duration were associated with impaired work performance (as measured by the number of work days hindered due to health problems, and self-ratings of work efficiency). However, while it is recognized that disability is a multi-dimensional construct, few studies have incorporated the various dimensions of disability within a broader biopsychosocial framework (Lederer, Loisel, Rivard, & Champagne, 2014). For example, the International Classification of Functioning, Disability and Health (ICF) framework (Cieza & Stucki, 2005) defines disability as an umbrella term that encompasses impairments in body functions; limitations in usual activities; and restrictions in the participation in household, social or work activities. Differential relationships between sleep and the various aspects of disability (i.e. difficulties in performing daily activities, reduced participation in recreation and leisure, limitations in carrying out daily routines, and troubles dealing with stress/psychological demands) may be important to comprehensively understand as this may point to potential target points for intervention (Litwiller et al., 2017).

Previous studies also have found that sleep may be linked with disability and functioning in the reverse direction (Litwiller et al., 2017; Magnavita & Garbarino, 2017). A 2017 longitudinal study of patients with chronic low back pain (Gerhart et al., 2017) found that poor sleep quality was associated with worse emotional and physical functioning, and that emotional functioning was associated with subsequent sleep quality. A 2017 study of USA private sector employees (Sin et al., 2017) found that daily measures of sleep quality were associated with next-day work stressors and negative affect (i.e. feeling distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery or afraid), and that positive affect was associated with next-day sleep outcomes. Following accumulated sleep loss, there may be changes in neural reactivity; amplifications of negative emotional reactions; increases in stress, irritability, anxiety and anger in response to stressful situations; and changes to cognitive anticipation of future emotional stimuli (Goldstein & Walker, 2014; Kahn, Sheppes, & Sadeh, 2013). In turn, these cognitive and emotional changes may lead to future sleep disruptions via a potential feedback loop (Goldstein & Walker, 2014; Kahn et al., 2013; Walker & Helm, 2009). However, there remains a gap in our understanding of the complex pathways that link sleep and disability/functioning (Litwiller et al., 2017), including the potential for reciprocal relationships between the two dimensions over time (Gerhart et al., 2017; Goldstein & Walker, 2014; Kahn et al., 2013; Sin et al., 2017).

In sum, while there is growing evidence that sleep may be linked with disability and functioning (e.g. activity limitations, participation restrictions and emotional functioning), previous studies tend to focus on physical versus emotional aspects of disability, rather than a comprehensive assessment of the various dimensions within one analytic model (Gradinger et al., 2011; Lederer et al., 2014; Linder et al., 2014; Litwiller et al., 2017). Moreover, previous studies on sleep and disability in the workplace are mostly based on cross-sectional data (Buxton et al., 2012; Linder et al., 2014; Niedhammer, David, Degioanni, Drummond, & Phillip, 2009; Van Mill et al., 2013), limiting the ability to account for complex and reciprocal relationships between sleep and disability across follow-up time. Finally, these relationships have yet to be examined comprehensively among injured workers with a workers' compensation claim, which is a

population that may be at greatest risk for sleep disturbances (Deyo et al., 2016; Solbach et al., 2018).

We conducted an analysis of longitudinal survey data to better understand the relationships between various dimensions of sleep disturbances and disability among a cohort of injured workers. This study aimed to examine: (a) the prevalence of sleep disturbances among a workers' compensation population with work-related injury and illness; (b) whether greater levels of disability and functioning (e.g. activity limitations, participation restrictions and emotional functioning) are longitudinally associated with sleep disturbance; and (c) whether there is evidence of a reciprocal relationship between the two dimensions.

2 | MATERIALS AND METHODS

2.1 | Data sources

Survey data were collected via computer-aided telephone interview as part of a prospective cohort study of workers' compensation claimants in Victoria, Australia. In Victoria, approximately 85% of the state's labour force is covered by the workers' compensation system, which provides insurance coverage for wage-replacement and health care expenditures in the event of a work-related injury or illness. Note that most employers are required to cover wage-replacement costs for the initial 10 days of incapacity, as well as healthcare costs below a certain threshold. The sampling frame, recruitment procedures and response rates are published in more detail elsewhere (Dimitriadis et al., 2017). In brief, the sampling frame was based on a population of claimants who were off work for 10 or more days as a result of a work-related injury, including psychological injuries (i.e. mental disorders such as post-traumatic stress disorder, other reactions to stressors and other mental disorders not elsewhere classified) and musculoskeletal conditions (i.e. all soft-tissue injuries of the back or upper extremity). Participants aged 18 years and older were recruited over the 2014–2015 period from monthly random samples of claimants identified by the compensation system. Baseline interviews (T1) were conducted shortly following the first day of incapacity (within approximately 2–5 months), with longitudinal follow-up occurring at 6 months (T2) and 12 months (T3) post-baseline.

Of the 869 claimants who participated at baseline, 632 (73%) completed the 6-month follow-up interview, 572 (66%) completed the 12-month follow-up interview, 504 (58%) completed both follow-up interviews, and 700 (81%) completed at least one interview. Cross-lagged path models were estimated using the dynamic panel that completed at least one follow-up interview (N = 700). Logistic regression examined the odds of participating in follow-up waves in relation to age, gender, injury type, return-to-work (RTW) status and disability levels at baseline. Analyses found that younger age groups (i.e. 18–34 years versus 55+ years, and 35–54 years versus 55+ years) were more likely to be lost to follow-up compared with the oldest age group. The other examined covariates were not associated with participation in follow-up waves.

Ethical approval was obtained from the Monash University Human Research Ethics Committee.

2.2 | Sleep disturbance

Sleep outcomes were measured at T2/T3 using seven items from the Patient-Reported Outcomes Measurement Information System (PROMIS) sleep disturbance questionnaire (Buysse et al., 2010). The PROMIS questionnaire provides a general measure of self-perceived severity of sleep disturbance in relation to sleep quality, depth and adequacy, as well as difficulty falling or staying asleep. All items were asked in reference to the past 7 days, with each item rated on a five-point scale ("Not at all" to "Very much"; "Never" to "Always"; "Very poor" to "Very good"). Positively worded items were reverse scored for analyses, so that higher levels corresponded to worse sleep disturbance. Consistent with PROMIS methodology, we converted the raw item scores to a standardized *T*-score ranging from approximately 29 to 76. This allows for comparability with the USA general/clinical reference population, which has a mean *T*-score of 50 and standard deviation of 10. Internal consistency reliability for the raw items was high (Cronbach's alpha 0.93). For descriptive analyses, we also examined a supplementary item that asked respondents to rate the extent to which their injury or workers' compensation claim had impacted their sleep in the past 7 days ("Not at all" to "Very much").

2.3 | Disability and functioning

Disability outcomes were measured at T1/T2/T3 based on a total of nine self-reported items that asked respondents whether they were unable to do certain things or perform certain activities as a result of their work-related physical or mental condition. Three items measured "*activity limitations* (*ACT*)", including difficulties performing simple actions (e.g. standing, reaching, sitting, walking), activities of daily living (e.g. getting dressed, eating, making dinner) or concentration activities (e.g. reading, driving). Three items measured "*participation restrictions* (*PART*)", relating to normal household activities (e.g. things normally done at home with family), social activities (e.g. with friends or family) or other regular activities (e.g. work, study). Finally, three items measured "*emotional functioning/feelings of disability* (*EMO*)", including how often their injury made them feel disabled; angry or frustrated; or dependent upon others. All disability items relate to impairments in body functions; limitations in usual activities; and restrictions in the participation in household, social or work activities, in accordance with the International Classification of Functioning, Disability and Health (ICF; Cieza & Stucki, 2005).

All nine items were asked in reference to the week prior to the survey, with each item rated on a five-point scale ("All of the time" to "None of the time"). Items were reverse scored so that higher levels corresponded to worse disability/functioning or greater feelings of each emotion (noting that greater feelings are not necessarily better or worse). Internal consistency reliability for all nine items was high

(Cronbach's alpha 0.91). For analyses, the mean item score was calculated for all nine items and for each of the three sub-dimensions.

2.4 | Covariates

We adjusted for pre-specified covariates found to be associated with disability and/or sleep disturbance in previous studies (Åkerstedt et al., 2015; Buxton et al., 2012; Litwiller et al., 2017; Magnavita & Garbarino, 2017; Magnusson Hanson et al., 2014). All items were measured at baseline, with the exception of current working status: age (18–34 years, 35–54 years, 55+ years); sex (male; female); injury type (musculoskeletal; psychological); current working status at each follow-up wave (yes; no); body mass index (BMI) calculated from height and weight (< 25 kg m^{-2}, 25–29 kg m^{-2}, 30+ kg m^{-2}); usual work hours (< 30 hr, 30–39 hr, 40+ hr); shift work (regular or day; night; rotating; irregular); union status of workplace (yes; no); size of workplace (1–19 employees; 20–99; 100+); self-reported psychosocial work conditions prior to injury (continuous scores for physical demands, mental demands and job autonomy).

We also adjusted for mental illness at T1/T2 based on six items from the K6 psychological distress scale (Kessler et al., 2010). This was done given the potential for strong links between sleep problems, emotional function and affective disorders (Adrien, 2002; Goldstein & Walker, 2014; Niedhammer et al., 2009). For example, sleep problems are strongly associated with future onset of depression (Biddle, Kelly, Hermens, & Glozier, 2018; Vitkova et al., 2018), with recent studies finding a bi-directional relationship between the two factors (Alvaro et al., 2013; Vitiello, 2018). For our study, scores on the K6 scale were summed to create a continuous variable (ranging from 0 to 24), with higher scores denoting greater mental illness.

2.5 | Analysis

Descriptive analyses (proportions, means) examined the distribution of baseline variables overall and by sex. The distribution of disability and sleep disturbance scores was compared across follow-up to examine changes in mean scores over time. We also calculated the prevalence of sleep disturbance at T2 and T3 (objective #1). Some cut-off thresholds have been proposed for clinically relevant sleep disturbance (Leung et al., 2016; Nagaraja et al., 2018), although no consensus on a definition exists. Thus, we report on the proportion of individuals with a *T*-score of 60+ and 70+, roughly equivalent to one and two standard deviations (respectively) worse than the reference values for the PROMIS calibration sample of USA general and clinical participants.

For objectives #2 and #3, cross-lagged path models examined the longitudinal relationship between disability (T1/T2) and sleep disturbances (T2/T3), and between sleep disturbances (T2) and disability (T3). In this approach, the *cross-lagged* (e.g. disability T2 to sleep T3; sleep T2 to disability T3), *cross-sectional* (e.g. disability T2 correlated with sleep T2) and *autoregressive* (e.g. disability from T2 to T3) pathways between disability and sleep are modelled simultaneously to estimate the longitudinal association between disability and sleep, net of cross-sectional correlations among concurrently measured variables and autocorrelations of each variable with the respective lagged measurement. A significant cross-lagged path between disability–sleep and/or sleep–disability indicates a directional association in either (or both) directions.

All model pathways were adjusted for the full set of covariates described above. Covariates with non-significant pathways were removed from the T2 → T3 pathway to improve model fit. Final models are presented without and with adjustment for mental illness scores. As mental illness may form part of the same concept as sleep problems or may lie on the temporal pathway between sleep and disability (Adrien, 2002; Alvaro et al., 2013; Biddle et al., 2018; Vitiello, 2018), we ran a factor analysis with the individual scale items for sleep, disability and mental health, which demonstrated that each of the three scales represented distinct constructs (results available upon request).

Data management and descriptive analyses were completed with SAS 9.4 (Cary, NC, USA). Path models were completed with Mplus 8 (Los Angeles, CA, USA) using the maximum likelihood option (MLR), which provides standard errors that are robust to potential non-normality of continuous variables. Missing data were accounted for by full-information maximum likelihood, under the assumption that missing data were missing at random. Variables with the largest proportion of missing data in the baseline sample were union status (7%), BMI (6%) and workplace size (4%). Goodness-of-fit of the final path model was indicated by Root Mean Square Error of Approximation (RMSEA) < 0.055, Standardized Root Mean Square Residual (SRMR) < 0.055, Comparative Fit Index (CFI) > 0.94, and Tucker Lewis Index (TLI) > 0.94. Unstandardized and standardized estimates with 95% confidence intervals are reported.

3 | RESULTS

3.1 | Study sample

Table 1 presents the distribution of study variables for the sample of respondents who completed at least one follow-up wave (*N* = 700). The overall sample was 46% female (*N* = 321). The majority had injury claims due to musculoskeletal injuries (77%), and had returned to work at baseline (58%). Eighty-four percent of the sample worked more than 30 hr per week, 59% worked in firms with 20 or more employees, and 63% worked in unionized firms.

3.2 | Prevalence of disability and sleep disturbance

Tables 2 and 3 present the mean scores for disability and sleep disturbance items across study follow-up. Mean scores for disability improved over time, with total summary measures (on a 1–5 scale) decreasing from 2.5 to 2.0 by the end of follow-up. Mean standardized

TABLE 1 Distribution of study variables at time of baseline survey: Victoria, Australia (*N* = 700)

	N	Col. %[a]
Age group (years)		
18–34	150	(21%)
35–54	381	(54%)
55+	169	(24%)
Sex		
Male	379	(54%)
Female	321	(46%)
Injury type		
Upper body or back MSI	540	(77%)
Psychological injury	160	(23%)
Return-to-work status		
Not working	292	(42%)
Working	408	(58%)
Work hours		
< 30	109	(16%)
30–39	327	(47%)
40+	260	(37%)
Shift work		
Regular schedule or day shift	497	(72%)
Night shift	40	(6%)
Rotating shift	108	(16%)
Irregular	48	(7%)
Workplace size		
Less than 20 employees	280	(41%)
20–99 employees	216	(32%)
100+ employees	180	(27%)
Union status		
No	242	(37%)
Yes	407	(63%)
BMI (kg m^{-2})		
<25	210	(32%)
25–29	236	(36%)
30+	216	(33%)
	Mean	***SD***
Work conditions		
Low physical demands (5–25)	10.6	(5.2)
Low psychological demands (6–30)	16.7	(6.1)
Job autonomy (5–25)	16.8	(5.2)
Mental illness		
K6 score (0–24)	8.3	(6.4)

BMI, body mass index; MSI, musculoskeletal injuries.

[a]Column percentages (col. %) reflect proportion of non-missing data, within each covariate.

t-scores for sleep disturbance ranged from 55.2 at T2 to 54.4 at T3. The proportion of individuals with sleep disturbance scores greater than one standard deviation above the reference mean (*T*-score 60+) was 36.4% at T2 and 31.1% at T3. The proportion of individuals with sleep disturbance scores greater than two standard deviations above the reference mean (*T*-score 70+) was 8.6% at T2 and 6.1% at T3. The proportion of respondents who rated their current sleep as being impacted "quite a bit" or "very much" by their injury and/or the workers' compensation process was 36.9% at T2.

3.3 | Cross-lagged path model

Figures 1 and 2 present the standardized path coefficients for the relationship between disability at T1/T2/T3 and sleep disturbance at T2/T3, with disability examined as a total summary score and as sub-dimensions in separate models (activity limitations, participation restrictions and emotional functioning). Across models, disability scores at T1 were associated with sleep disturbance at T2 follow-up in the models without and with adjustment for mental illness, although the estimates were attenuated after adjustment. In the cross-lagged portion of the model, participation restrictions and emotional functioning at T2 were associated with sleep disturbance at T3 and vice versa in the models unadjusted for mental illness. However, once mental illness was included in the models, only emotional functioning at T2 remained significantly associated with subsequent sleep disturbance at T3. Specifically, each unit increase in emotional functioning at T2 (which ranged from 1 to 5) was associated with a 1.1 unit increase in sleep disturbance at T3 (which ranged from 29 to 76). Disability and sleep scores had a strong cross-sectional association within waves, and each dimension was autoregressively associated with itself over time. Model fit indices for the fully adjusted model were within ideal ranges (e.g. EMO fully adjusted model: RMSEA: 0.048; SRMR: 0.006; CFI 0.99; TLI 0.92; see Appendix 1 for the unstandardized path coefficients).

4 | DISCUSSION

This study aimed to examine the longitudinal relationship between disability and sleep among injured workers using survey data collected across three follow-up points. Our findings are novel in that we incorporated a stronger conceptualization of disability within one comprehensive framework while utilizing appropriate analytic models to better understand the potential for reciprocal relationships over time. Our study has three main findings in relation to study objectives. First, we observed a high prevalence of sleep disturbance among our sample of workers' compensation claimants with a work-related injury, with nearly one-in-three workers reporting a moderate to severe sleep disturbance at 6 months of follow-up. Second, we found that some aspects of disability (specifically, emotional functioning) were longitudinally associated with sleep disturbances.

TABLE 2 Distribution (*N*, column %) and mean (standard deviation) scores for disability variables across follow-up waves

	T1[a]		T2		T3	
	N = 700		*N* = 632		*N* = 572	
	N	Col. %	*N*	Col. %	*N*	Col. %
Activity limitations (% "Most of the time" or "All of the time")						
Simple actions (standing, reaching, sitting or walking)?	148	21.1%	116	18.4%	84	14.7%
Physical co-ordination activities (getting dressed, eating, cooking)?	135	19.3%	81	12.8%	68	11.9%
Concentration activities (reading, watching TV, driving)?	108	15.4%	76	12.0%	62	10.8%
Participation restrictions (% "Most of the time" or "All of the time")						
Participation in normal household activities (at home or with family)?	188	26.9%	128	20.3%	101	17.7%
Participation in normal social activities (friends, family or neighbours)?	181	25.9%	124	19.6%	96	16.8%
Participation in other regular activities (work, study)?	243	34.7%	153	24.2%	117	20.5%
Emotional functioning (% "Most of the time" or "All of the time")						
Injury made you feel disabled?	197	28.1%	144	22.8%	99	17.3%
Injury made you feel angry and frustrated?	252	36.0%	164	25.9%	132	23.1%
Injury made you feel dependent upon others?	188	26.9%	140	22.2%	105	18.4%
	Mean	***SD***	**Mean**	***SD***	**Mean**	***SD***
Summary mean scores[b]						
Activity limitations (1–5)	2.1	(1.1)	1.9	(1.1)	1.8	(1.1)
Participation restrictions (1–5)	2.6	(1.3)	2.3	(1.3)	2.1	(1.2)
Emotional functioning (1–5)	2.7	(1.2)	2.4	(1.3)	2.1	(1.2)
Total score (1–5)	2.5	(1.1)	2.2	(1.1)	2.0	(1.1)

[a]T1 baseline; T2 first wave of follow-up; T3 second wave of follow-up.

[b]Higher scores denote greater limitations, restrictions, or feelings of disability.

Third, in our initial models, we found evidence of reciprocal relationships over time between each of the disability dimensions and sleep disturbances, and vice versa. However, adjustment for mental illness attenuated the reciprocal relationships to non-significance. Together, these findings suggest the potential for longitudinal links between disability/sleep, although there are complex associations between the two factors in relation to mental illness that may be important to address methodologically and analytically.

4.1 | Objective #1: Prevalence of sleep disturbance

Sleep disturbance was prevalent in our study sample of workers' compensation claimants with work-related injuries and illnesses. Mean *T*-scores for sleep disturbance across follow-up waves were similar to, or higher than, values reported from clinical reference populations (Deyo et al., 2016; Leung et al., 2016; Nagaraja et al., 2018); and higher than the reference values (*T*-score 50) for the PROMIS calibration sample of general and clinical participants. We also found a large proportion of respondents with *T*-score values above the various cut-off thresholds for clinically relevant sleep disturbance (Leung et al., 2016; Nagaraja et al., 2018), with approximately 36% of the sample having moderate to severe sleep disturbance (i.e. greater than one standard deviation above the reference *T*-score value) following work injury.

These findings are consistent with existing reports of a high prevalence of sleep problems among the general working population (Adams et al., 2017; Luckhaupt et al., 2010; Morin et al., 2011), but extend the existing literature by using a focused sample of workers' compensation claimants with a work-related injury. In our study, a large proportion of respondents also rated their current sleep as being impacted "quite a bit" or "very much" by their injury and/or the workers' compensation process. Thus, given the high burden of sleep problems and potential impact of the injury and claim process, our findings highlight the importance of considering the broader contextual environment when developing interventions that address sleep problems throughout the course of recovery (Pomaki, Franche, Murray, Khushrushahi, & Lampinen, 2012).

TABLE 3 Distribution (*N*, column %) and mean (standard deviation) scores for sleep disturbance variables across follow-up waves

	T2[a,b]		T3		
	N = 632		*N* = 572		Trend over time
	N	Col. %	*N*	Col. %	*p*-value
Item scores (% with worse scores)[c]					
Was your sleep restless? (Quite a bit/very much)	262	42.0%	221	38.8%	.154
Were you satisfied with your sleep? (A little bit/not at all)	318	50.9%	257	44.9%	.015
Did you have difficulty falling asleep? (Quite a bit/very much)	200	31.9%	174	30.4%	.475
Did you have trouble staying asleep? (Often/always)	269	42.8%	225	39.5%	.137
Did you have difficulty sleeping? (Often/always)	258	41.1%	216	37.8%	.118
Did you get enough sleep? (Rarely/never)	223	35.7%	191	33.5%	.330
Would you say your sleep quality was… (Poor/very poor)	261	41.5%	202	35.4%	.006
Impact of injury or claim on sleep? (Quite a bit/very much)[d]	230	36.9%	152	26.7%	<.001
Continuous score prevalence (% above *T*-score threshold)					
50+	447	71.1%	393	68.7%	.237
55+	326	51.8%	288	50.3%	.482
60+	229	36.4%	178	31.1%	.010
65+	133	21.1%	90	15.7%	.002
70+	54	8.6%	35	6.1%	.065
	Mean	*SD*	Mean	*SD*	*p*-value
Continuous scores[c]					
T-score (29–76)	55.2	(11.4)	54.4	(10.5)	.071

[a]T1 baseline; T2 first wave of follow-up; T3 second wave of follow-up.

[b]Sleep disturbances were not assessed at T1.

[c]Higher scores denote worse levels of sleep disturbance.

[d]This item was supplementary and not included in the calculation of summary sleep disturbance scores.

4.2 | Objectives #2 and #3: Disability and sleep disturbances

Our findings were in support of a longitudinal relationship between each of the disability dimensions and subsequent sleep disturbances, although only emotional functioning was consistently linked with sleep disturbance across models after accounting for mental illness. The strong link between emotional functioning and sleep problems has been noted in previous studies, as described in the Introduction. One potential explanation for these findings is the role of neurobiological mechanisms (Goldstein & Walker, 2014; Kahn et al., 2013; Smith & Haythornthwaite, 2004; Walker & Helm, 2009), which may be responsible for amplifications of negative emotional reactions; subsequent increases in stress, irritability, anxiety and anger in response to stressful situations; conditioning of arousal due to time spent awake while in the bedroom environment; and changes in the cognitive anticipation of future emotional stimuli as a result of sleep disturbances.

In our study, activity limitations and participation restrictions were also associated with subsequent sleep disturbances across follow-up, although these relationships were attenuated to non-significance once mental illness was controlled for. Given the complexity of the relationship between sleep disturbances and psychopathological variables (Adrien, 2002; Goldstein & Walker, 2014; Niedhammer et al., 2009), we chose to present our models without and with control for mental distress in our path models. Although factor analyses suggested that the dimensions of sleep, disability and mental illness represented distinct constructs, we note that this may result in over-adjustment if distress forms part of the same concept as sleep problems or lies on the temporal pathway between sleep and disability (Niedhammer et al., 2009; Vitkova et al., 2018). Nevertheless, the proportion of the relationship between sleep and disability that was accounted for by the inclusion of mental health status demonstrates the complexity of the theoretical relationships. Our findings extend previous research by separating the various cross-lagged pathways

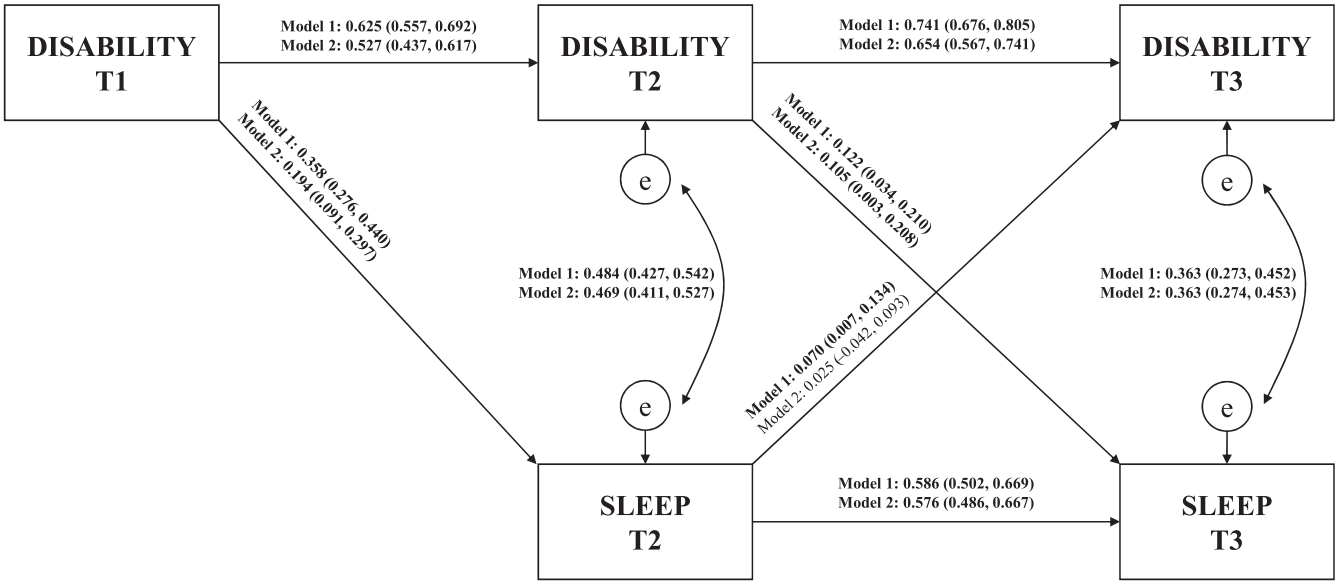


FIGURE 1 Cross-lagged path models (standardized beta coefficients; 95% confidence intervals) for the relationship between T1/T2/T3 disability (mean score across items) and T2/T3 sleep disturbance. Model 1 is without adjustment for mental illness score; Model 2 is with adjustment.[a,b,c,d]. [a]T1 = baseline; T2 = 6-months follow-up; T3 = 12-months follow-up; E = residual variance. [b]Higher scores denote greater limitations, restrictions or feelings of disability; and worse sleep disturbance. [c]Model 1 adjusts for age, sex, injury type, baseline return-to-work (RTW) status, body mass index (BMI), work schedule, workplace size, union status and self-reported work conditions. [d]Model 2 adjusts for Model 1 covariates, plus K6 psychological distress score

between sleep, disability and mental illness using longitudinal survey data and appropriate analytic models. However, future work should continue to examine the individual relationships between sleep and disability with other dimensions of mental health, as well as mediating pathways between the factors to identify target points for intervention (Kahn et al., 2013; Whibley et al., 2019).

4.3 | Implications

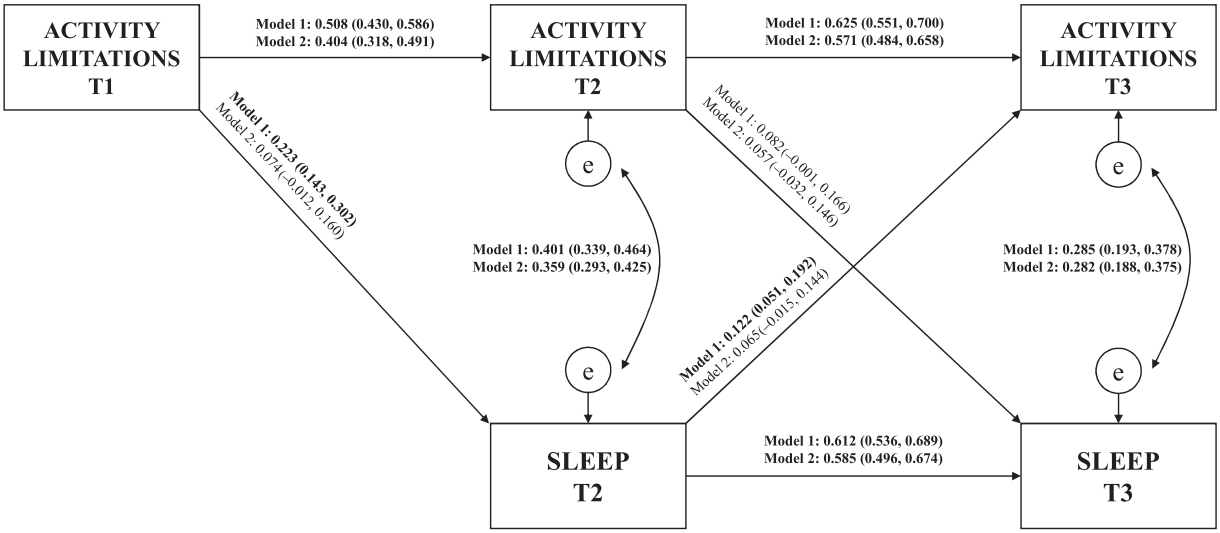
These findings have several implications for research and policy. First, the significant autocorrelative relationships observed within each dimension across follow-up waves demonstrate the need to incorporate lagged measures of disability and sleep in future studies. The choice of lag-time may also be reflective of either accumulative or acute processes that link sleep with disability (Goldstein & Walker, 2014; Sin et al., 2017), and thus future research should examine additional measurement lags based on the hypothesized causal mechanism. Second, the consistent links between emotional functioning and sleep problems (but not the other disability dimensions) suggest the importance of this factor as a potential target point for intervention. For example, previous systematic reviews have found that interventions such as clinical treatment, workplace-based psychological interventions, and navigational help throughout the recovery and claim process have been shown to be effective in improving work functioning and quality of life outcomes among worker populations (Pomaki et al., 2012; van Vilsteren et al., 2015). These interventions could be targeted towards individuals who feel disabled, angry or frustrated following a workplace injury as a way to reduce sleep disturbances. However, future work should identify specific aspects of emotional functioning that could be better supported among injured workers, and examine the impact of potential interventions via evaluation studies (Kahn et al., 2013; Whibley et al., 2019). Finally, a proportion of the relationship between disability/functioning and sleep was accounted for by the inclusion of lagged mental health status, demonstrating the complexity of the causal relationships and the need to analyse each variable within a comprehensive model. Moreover, individuals with sleep problems might benefit from interventions that aim to promote mental health and reduce mental illness in the workplace (Joyce et al., 2016; Pomaki et al., 2012).

4.4 | Strengths and limitations

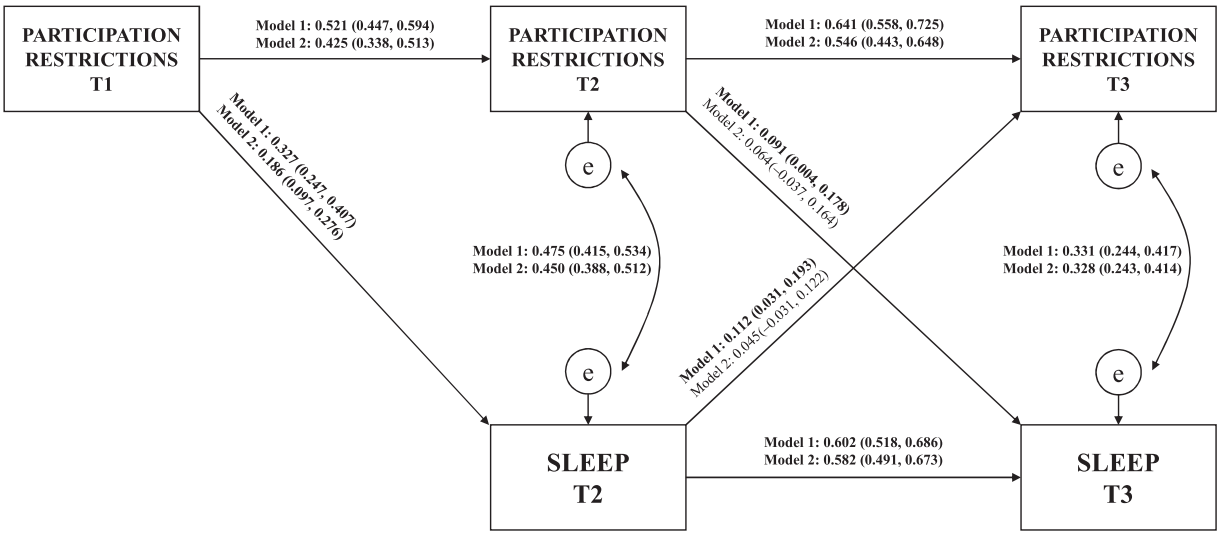
A strength of this study is the use of prospectively collected data with longitudinal assessment of sleep and disability across three equally spaced follow-up waves. This allowed for a robust modelling

FIGURE 2 Cross-lagged path models (standardized beta coefficients; 95% confidence intervals) for the relationship between T1/T2/T3 disability dimensions and T2/T3 sleep disturbance. Model 1 is without adjustment for mental illness score; Model 2 is with adjustment.[a,b,c,d]. [a]T1 = baseline; T2 = 6-months follow-up; T3 = 12-months follow-up; E = residual variance. [b]Higher scores denote greater limitations, restrictions or feelings of disability; and worse sleep disturbance. [c]Model 1 adjusts for age, sex, injury type, baseline return-to-work (RTW) status, body mass index (BMI), work schedule, workplace size, union status and self-reported work conditions. [d]Model 2 adjusts for Model 1 covariates, plus K6 psychological distress score

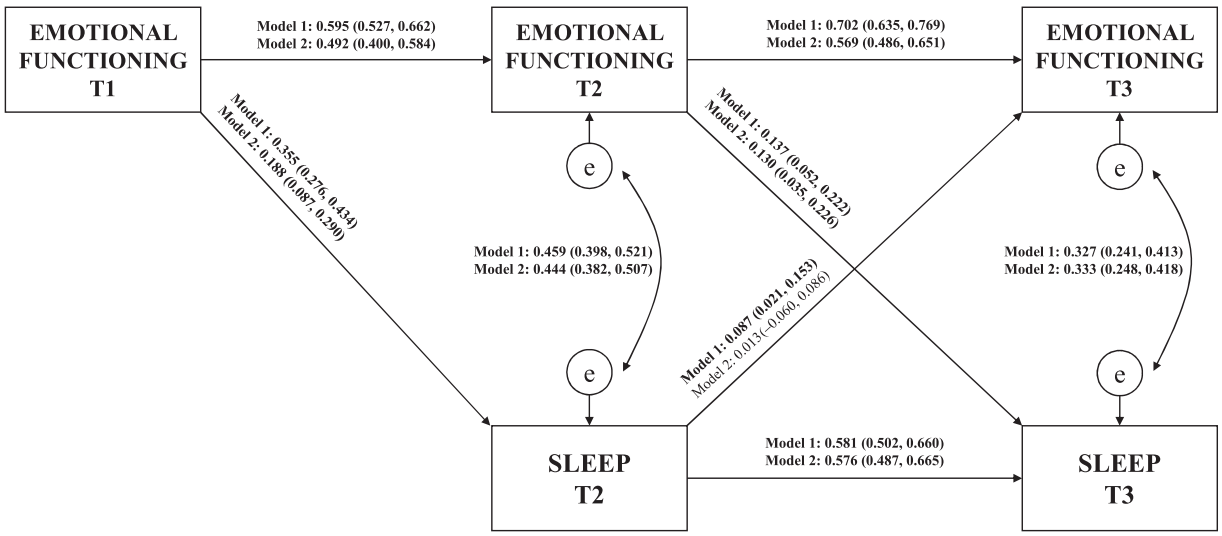
(a) Activity limitations:



(b) Participation restrictions:



(c) Emotional functioning:



strategy that accounted for the longitudinal structure of the data (i.e. cross-sectional correlations across concurrently measured variables and autocorrelation over time). The use of a standardized measure of sleep disturbance enhances the validity, reliability and comparability of our key outcome measures. We also examined various dimensions of disability (i.e. activity limitations, participation restrictions, impairments) within the framework of a comprehensive, biopsychosocial disability model (Cieza & Stucki, 2005).

An inherent limitation of cross-lagged path models is the potential for over-estimation of the autocorrelation coefficients among the repeated measures over time. There may also be other variables such as pain levels, health-related work limitations or workplace bullying (Litwiller et al., 2017; Magnavita & Garbarino, 2017; Niedhammer et al., 2009; Whibley et al., 2019) that were not measured for our study sample. This may result in residual confounding of the cross-lagged pathways. However, we adjusted our models for a wide range of sociodemographic, clinical, psychosocial and work characteristics of relevance to sleep and work outcomes (Litwiller et al., 2017; Magnavita & Garbarino, 2017), including lagged measures of mental illness across follow-up. Finally, study findings were based on a sample of claimants who had a work-related psychological or musculoskeletal injury that resulted in 10 or more days of work absence. Results may not be generalizable to non-compensation populations or to those with less severe/different types of injuries. However, our findings provided additional insight into the relationships between sleep and disability among a focused sample of injured workers, which has been lacking in the existing body of research (Litwiller et al., 2017).

5 | CONCLUSIONS

Given that a significant proportion of the reciprocal relationship between sleep and disability/functioning was accounted for by mental health status, our findings demonstrate the complexity of the causal relationships and the need to analyse each variable within a comprehensive, longitudinal model. On the other hand, the consistent links between emotional functioning and sleep problems suggest the importance of these factors as potential target points for intervention. Future work should focus on identifying specific aspects of emotional functioning (such as feelings of disability, anger and frustration) and mental health/illness that could be better supported following a workplace injury as a way to address the high burden of sleep problems among injured workers. This work could include a focus on mediating pathways between sleep, disability and mental health; or evaluation studies that assess the impact of clinical/workplace-based psychological interventions and claim management activities. Future research should also continue to capture multiple assessments of disability, sleep and mental health over time to better account for temporal ordering of measurements.

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AUTHOR CONTRIBUTIONS

JKF conceived the study, conducted the analysis and drafted the manuscript. PMS conceived the study, guided the analysis and helped draft the manuscript. All authors (including MS, RL, ISW) reviewed the data analysis, contributed to the manuscript preparation and approved the final manuscript.

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APPENDIX 1

TABLE A1 Cross-lagged path models (unstandardized beta coefficients; 95% confidence intervals) for the relationship between T1/T2/T3 disability dimensions and T2/T3 sleep disturbance. Model 1 is without adjustment for mental illness score; Model 2 is with adjustment[a,b,c,d]

	T1 → T2		T2 → T3	
	Model 1: No MI	**Model 2: MI**	**Model 1: No MI**	**Model 2: MI**
(a) Total disability score:				
Cross-lagged				
Disability to sleep	**3.711 (2.849, 4.573)**	**2.012 (0.946, 3.078)**	**1.165 (0.324, 2.005)**	**1.008 (0.030, 1.985)**
Sleep to disability	-	-	**0.007 (0.001, 0.013)**	0.002 (−0.004, 0.009)
Autoregressive				
Disability to disability	**0.628 (0.555, 0.700)**	**0.529 (0.436, 0.622)**	**0.747 (0.674, 0.819)**	**0.661 (0.569, 0.753)**
Sleep to sleep	-	-	**0.544 (0.458, 0.629)**	**0.535 (0.443, 0.627)**
Concurrent				
Disability with sleep	**3.876 (3.195, 4.557)**	**3.627 (2.976, 4.277)**	**1.818 (1.258, 2.377)**	**1.800 (1.246, 2.354)**
	T1 → T2		**T2 → T3**	
	Model 1: No MI	**Model 2: MI**	**Model 1: No MI**	**Model 2: MI**
(b) Activity limitations:				
Cross-lagged				
Disability to sleep	**2.285 (1.467, 3.103)**	0.759 (−0.126, 1.643)	0.822 (−0.006, 1.651)	0.569 (−0.320, 1.457)
Sleep to disability	-	-	**0.011 (0.005, 0.018)**	0.006 (−0.001, 0.014)
Autoregressive				
Disability to disability	**0.484 (0.402, 0.566)**	**0.385 (0.298, 0.473)**	**0.635 (0.552, 0.719)**	**0.580 (0.486, 0.674)**
Sleep to sleep	-	-	**0.568 (0.487, 0.648)**	**0.543 (0.452, 0.634)**
Concurrent				
Disability with sleep	**3.467 (2.774, 4.159)**	**2.882 (2.233, 3.531)**	**1.557 (0.968, 2.146)**	**1.523 (0.932, 2.114)**
	T1 → T2		**T2 → T3**	
	Model 1: No MI	**Model 2: MI**	**Model 1: No MI**	**Model 2: MI**
(c) Participation restrictions:				
Cross-lagged				
Disability to sleep	**2.882 (2.165, 3.600)**	**1.640 (0.850, 2.430)**	**0.766 (0.038, 1.494)**	0.537 (−0.307, 1.380)
Sleep to disability	-	-	**0.012 (0.003, 0.021)**	0.005 (−0.003, 0.013)
Autoregressive				
Disability to disability	**0.506 (0.431, 0.581)**	**0.413 (0.327, 0.500)**	**0.631 (0.544, 0.719)**	**0.538 (0.434, 0.643)**
Sleep to sleep	-	-	**0.559 (0.472, 0.645)**	**0.540 (0.448, 0.632)**
Concurrent				
Disability with sleep	**4.704 (3.884, 5.525)**	**4.245 (3.459, 5.030)**	**2.123 (1.458, 2.788)**	**2.076 (1.425, 2.727)**

(Continues)

TABLE A1 (Continued)

	T1 → T2		T2 → T3	
	Model 1: No MI	**Model 2: MI**	**Model 1: No MI**	**Model 2: MI**
(d) Emotional functioning:				
Cross-lagged				
Disability to sleep	**3.223 (2.487, 3.960)**	**1.710 (0.781, 2.639)**	**1.149 (0.437, 1.861)**	**1.093 (0.292, 1.895)**
Sleep to disability	-	-	**0.010 (0.002, 0.017)**	0.001 (−0.007, 0.010)
Autoregressive				
Disability to disability	**0.598 (0.526, 0.670)**	**0.494 (0.400, 0.589)**	**0.704 (0.627, 0.781)**	**0.572 (0.484, 0.660)**
Sleep to sleep	-	-	**0.540 (0.458, 0.621)**	**0.535 (0.445, 0.625)**
Concurrent				
Disability with sleep	**4.296 (3.492, 5.100)**	**4.032 (3.250, 4.815)**	**1.933 (1.309, 2.556)**	**1.916 (1.306, 2.525)**

[a]T2 = 6-months follow-up; T3 = 12-months follow-up.

[b]Higher scores denote greater limitations, restrictions or feelings of disability (range 1–5); and worse sleep disturbance (range approx. 29–76).

[c]Model 1 adjusts for age, sex, injury type, baseline RTW status, body mass index, work schedule, workplace size, union status, and self-reported work conditions.

[d]Model 2 adjusts for Model 1 covariates, plus K6 psychological distress score.