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Examining Exposure Assessment in Shift Work Research: A Study on Depression Among Nurses

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Abstract

Introduction: Coarse exposure assessment and assignment is a common issue facing epidemiological studies of shift work. Such measures ignore a number of exposure characteristics that may impact on health, increasing the likelihood of biased effect estimates and masked exposure–response relationships. To demonstrate the impacts of exposure assessment precision in shift work research, this study investigated relationships between work schedule and depression in a large survey of Canadian nurses.
Methods: The Canadian 2005 National Survey of the Work and Health of Nurses provided the analytic sample (n = 11 450). Relationships between work schedule and depression were assessed using logistic regression models with high, moderate, and low-precision exposure groupings. The high-precision grouping described shift timing and rotation frequency, the moderate-precision grouping described shift timing, and the low-precision grouping described the presence/absence of shift work. Final model estimates were adjusted for the potential confounding effects of demographic and work variables, and bootstrap weights were used to generate sampling variances that accounted for the survey sample design.
Results: The high-precision exposure grouping model showed the strongest relationships between work schedule and depression, with increased odds ratios [ORs] for rapidly rotating (OR = 1.51, 95% confidence interval [CI] = 0.91–2.51) and undefined rotating (OR = 1.67, 95% CI = 0.92–3.02) shift workers, and a decreased OR for depression in slow rotating (OR = 0.79, 95% CI = 0.57–1.08) shift workers. For the low- and moderate-precision exposure grouping models, weak relationships were observed for all work schedule categories (OR range 0.95 to 0.99).
Conclusions: Findings from this study support the need to consider and collect the data required for precise and conceptually driven exposure assessment and assignment in future studies of shift work and health. Further research into the effects of shift rotation frequency on depression is also recommended.

Keywords: exposure assessment methodology; exposure assignment; exposure categories; nurses; shift work; work schedule

Introduction

Exposure assignment is the application of exposure categories or levels to study subjects. This aspect of exposure assessment is a fundamental consideration in an epidemiological study, since it is the basis for comparing health outcomes across groups with differing amounts or types of exposure to a hazard.

A recognized challenge in the field of shift work and health research is that 'exposure' to shift work encompasses a variety of different scheduling, work environment, social, and individual characteristics (Costa 2003). The common assignment of coarse exposure indicators (e.g. 'day worker' versus 'night worker') in epidemiological studies ignores a number of potentially important exposure characteristics of shift work (e.g. shift timing, rotation frequency) that may impact on health (Stevens *et al.* 2011).

This trend is problematic since crude exposure assessment and assignment can produce measurement error and exposure misclassification within groups (Loomis and Kromhout 2004) that can attenuate true effects and mask exposure–response relationships. A similar point was demonstrated in a large Swedish cohort study that examined shift work's effects on the risk of myocardial infarction (Alfredsson *et al.* 1985). When shift work was defined as 'not day work', the Standardized Mortality Ratio (SMR) was 115% (95% confidence interval [CI]: 104–126), whereas when shift work was defined more precisely as 'night shift', the SMR increased to 148% (95% CI: 112–191; Knutsson 2004).

Although calls have been made to improve the quality of exposure assessment in epidemiological studies of shift work (Knutsson 2004; Härmä and Kecklund 2010; Stevens *et al.* 2011; Saksvik *et al.* 2011), coarse categorizations are still commonly used to assign exposures in studies of shift work and health. In an effort to further understand and characterize the impact of exposure assessment precision in epidemiological studies of shift work, the current study examined associations between work schedule and depression.

A number of physiological and social pathways may link shift work exposure with pathological mood and depression outcomes, including exposure to light at night, disrupted circadian rhythms (including sleep and melatonin release), and altered social functioning (Grandin *et al.* 2006; McClung 2013). However, evidence linking shift work with an increased risk of negative mental health outcomes is mixed, perhaps due in part to the positive effects of work in general for mental health and well-being (Waddell and Burton 2006) versus the negative effects of suboptimal work conditions for mental health (Harvey *et al.* 2017). Few studies have sought to investigate the effects of work schedule on depression, and fewer have used refined measures of shift work to investigate exposure–response relationships. For example, shift rotation frequency (referring to the number of shift changes in a given time period) could be an important exposure characteristic to assess in studies of shift work and mental health. A high shift rotation frequency increases the likelihood of 'quick returns' between shifts; that is, changeovers from morning/day to night shifts, night to evening shifts, or evening to morning/day shifts where 11 hours or less of free time is scheduled between shifts (Council of the European Union EP 2003). Quick returns, identified as a 'big problem in life' by some shift workers (Åkerstedt and Kecklund 2017), have been associated with poor sleep quality, increased fatigue, and disrupted social relationships (Vedaa *et al.* 2016). High shift rotation frequency may also reflect precarious employment situations (Quinlan *et al.* 2001) that have been associated with increased social disruption, stress, and depressive symptoms (Burgard *et al.* 2009; Kim *et al.* 2016; Lewchuk and Lafleche 2017).

Major depressive disorder is experienced by 5% of the Canadian adult population annually (Patten *et al.* 2016) and represents a significant source of disability and economic burden (Lim *et al.* 2008). Nurses, the largest occupational group in Canada's health sector, experience particularly high rates of both depression (Shields and Wilkins 2006) and shift work (Shields and Wilkins 2006) compared to the general working population (Shields 2006; Williams 2008). A large national survey of Canadian nurses (Shields and Wilkins 2006) offered a unique opportunity to investigate the impacts of exposure assignment on relationships between work schedule and depression, through the use of exposure groupings with varying degrees of precision. The current study was particularly interested in examining relationships between shift rotation frequency and depression, since this had not previously been done. The hypotheses were:

(1) Associations between work schedule and depression will strengthen as the precision of exposure groupings increases; and
(2) Nurses involved in regular night work and high frequency rotation shift work will have an increased odds of depression relative to nurses in regular daytime schedules.

Methods

Data source

Data for this study were obtained from the National Survey of the Work and Health of Nurses (NSWHN), 2005, via Statistics Canada's Research Data Centres

Program (Statistics Canada 2017). The NSWHN was a cross-sectional survey conducted by the Canadian Institute for Health Information and Statistics Canada to provide a picture of the health and working conditions of nurses at a national level. The target population was regulated nurses (registered nurses, registered psychiatric nurses, and licensed practical nurses) aged 21 years or older who were registered and employed in Canada at the time of survey. To construct the sampling frame, Statistics Canada received membership lists from all nursing organizations and regulatory bodies in each of the 10 provincial and 3 territorial jurisdictions in Canada. From a national total of 331 992 nurses, 24 443 were selected at random using a stratified design to ensure adequate sample sizes for each jurisdiction and for each type of regulated nurse (registered nurse, licensed practical nurse, and registered psychiatric nurse). Within these strata, secondary stratification was conducted for age group, place of work (hospital, long-term care facility, community health setting, and other), and employment status (full-time, part-time, and casual). Computer-assisted telephone interviewing was carried out by trained interviewers between October 2005 and January 2006 to obtain a survey sample size of 18 676 (response rate = 79.7%). Further details of the NSWHN survey measures, methodology, and quality control methods have been reported by Statistics Canada (Statistics Canada 2006).

Study sample

To increase the precision of exposure groupings based on working conditions and health in the 12 months prior to survey interview, and to enhance the comparability of exposure-response relationships across exposure grouping categories, the analyses excluded individuals who were employed in more than one nursing job (n = 2846), not exclusively providing direct care to patients or residents (n = 3222), employed in their current position for <12 months (n = 209), temporarily absent from their nursing position for 12 months or more at time of interview (n = 104), and self-employed (n = 295). The sample was further restricted to individuals with valid responses for the outcome variable, primary explanatory variable, and all other co-variables included in the analyses. These criteria produced an unweighted sample size of n = 11 450 respondents.

Study variables

The outcome variable was major depressive disorder occurring within the 12 months prior to interview. The NSWHN interview utilized a predictive instrument called the Composite International Diagnostic Interview Short Form, Major Depression section (CIDI-SFMD), an instrument developed by Kessler and colleagues (1994, 1998) to evaluate the likelihood of presence of major depressive disorder. The CIDI-SFMD was derived from a subset of items from the Composite International Diagnostic Interview (CIDI), a validated (Kessler *et al.* 1998; Patten *et al.* 2000) World Health Organization-endorsed tool that has been used successfully in other studies. Prior validation studies have indicated that 75 to 90% of participants reporting five or more major depression symptoms on the CIDI-SFMD (approximating symptoms listed in the Diagnostic and Statistical Manual of Mental Disorders, 3rd Edition (DSM-III-R) criteria for major depression; (American Psychiatric Association 1987) have had a major depression episode in the preceding 12 months (Kessler *et al.* 1998; Patten *et al.* 2000). Based on these findings, depression categories for the current study were dichotomized into 'Yes' (respondent indicates five or more major depression symptoms on the CIDI-SFMD) and 'No' (respondent indicates fewer than five major depression symptoms on the CIDI-SFMD).

The primary explanatory variable was work schedule. Three sets of work schedule exposure groupings were derived from questions pertaining to work hours at respondents' main job (referring to the nursing job at which the nurse usually worked the most hours). These were: 'Do you usually work days, evenings, or nights?', and (for Exposure Grouping 1 only) 'In the past 2 weeks, how many times did you change shifts (for example, from days to evenings, or evenings to nights)?'.

Exposure Grouping 1—High-Precision Work Schedule, seven categories (considers shift timing and rotation frequency):

(1) Regular Days
(2) Regular Evenings
(3) Regular Nights
(4) Slow Frequency Rotating Shifts (0–1 shift changes in past 2 weeks);
(5) Medium Frequency Rotating Shifts (2–3 shift changes in past 2 weeks);
(6) Rapid Frequency Rotating Shifts (4+ shift changes in past 2 weeks);
(7) Undefined Frequency Rotating Shifts (reported rotating shifts but did not work in past 2 weeks; could not be classified).

Exposure Grouping 2—Moderate-Precision Work Schedule, four categories (considers shift timing only):

(1) Regular Days
(2) Regular Evenings

(3) Regular Nights
(4) Rotating Shifts

Exposure Grouping 3—Low-Precision Work Schedule, two categories (considers absence/presence of shift work only):

(1) Regular Days
(2) Any work outside of regular daytime hours (regular evenings, regular nights, or rotating shifts)

Additional variables

The NSWHN asked a number of questions about sociodemographic, health, and work characteristics, including psychosocial work factors that have been linked to depression (Niedhammer *et al.* 2015). Since this study's goal was to measure the relationship between work schedule and depression, only variables with the potential to confound this relationship (and unlikely to lie on the causal pathway) were sought for inclusion in the models. Determinants or risk factors for depression that are unrelated to work schedule, and therefore not confounders of the relationship under investigation, were also excluded from the analyses. This was done using a priori knowledge and causal diagrams to conceptualize relationships between variables.

Psychosocial work factors (e.g. high psychological demands, low social support) may be implicated in the aetiology of depression (Bonde 2008; Netterstrøm *et al.* 2008; Siegrist 2008). All psychosocial work variables available in the survey (job strain, role overload, autonomy, control, psychological demands, social support, organizational support, and scheduling flexibility) were entered individually into a preliminary logistic model of depression and work schedule (high-precision definition) to identify the strongest potential confounders for retention in the final model. Only autonomy, organizational support, and scheduling flexibility produced a substantial (>10%) shift in the point estimates for the effect of work schedule on depression. Examination of cross-tabs and Pearson chi-square tests showed strong interrelations between these three variables. Out of these three variables, scheduling flexibility was hypothesized as the most likely to influence work schedule, rather than to lie on the causal pathway between work schedule and depression. Conversely, an individual's work schedule may affect perceptions of autonomy (for example, there may be greater opportunity for independent decision making during a night shift with less supervisory presence), and of organizational support (potentially related to factors such as supervisory presence, or fewer staff scheduled at night). Since our goal was to measure the relationship between work schedule and depression without the potential mediating effects of other variables, the scheduling flexibility variable was chosen for retention in the final models.

The following additional variables were included in the models as potential confounders since they are risk factors for depression and other mental health outcomes, and may also be related to work schedule: age (Gilmour and Patten 2007; Ferrari *et al.* 2013), sex (Alonso *et al.* 2004), family/living situation (Gilmour and Patten 2007), socioeconomic status (Alonso *et al.* 2004; Gilmour and Patten 2007), presence of chronic health conditions (Patten *et al.* 2005; Gilmour and Patten 2007), scheduling flexibility (Nijp *et al.* 2012), workplace type (Cocco *et al.* 2003), overtime (Virtanen *et al.* 2011), and typical shift duration (Lowden *et al.* 1998) see Table 1 for detailed categories. Since these variables were selected based on a priori reasoning, all were retained in the final models.

Statistical analyses

Analyses were conducted through the Statistics Canada's Research Data Centres Program (Statistics Canada 2017) at the University of British Columbia, using SAS version 9.4. All bivariable cell sizes were 30 observations or more, as required for confidential data release by Statistics Canada. To appropriately account for the NSWHN sampling procedures (Statistics Canada 2006), probability survey weights provided by Statistics Canada were applied in all analyses to produce variance estimates that adjusted for the sampling strategy and reduced bias in the estimates obtained.

The NSWHN's multi-stage survey design requires an approximation method to calculate variance estimates. The bootstrapping technique conducted by Statistics Canada for this survey can be briefly summarized as follows: Within each survey stratum, a simple random sample was selected, with replacement, from $n-1$ clusters. This process was repeated 500 times, creating 500 new samples (or replicates). The standard deviations of the point estimates for each of the 500 samples within each stratum were calculated and used by Statistics Canada to develop final bootstrap weights. These weights were applied to the study's adjusted results to estimate the variance (i.e. the observed variance of the 500 point estimates is the bootstrapped estimate of variance). Further information on the bootstrapping technique employed by Statistics Canada is available elsewhere (Kleim and Belanger 2007).

Crude odds ratios [ORs] with 95% CIs were calculated for the relationship between work schedule and depression. Logistic regression was conducted to assess

Table 1. Baseline study sample characteristics and bivariable associations with depression (within previous 12 months): National Survey of the Work and Health of Nurses (NSWHN), 2005.[a]

	Frequency (n = 11 450)	(%)	Depression No (%)	Depression Yes (%)
Depression				
No	10 446	90.9		
Yes	1004	9.1		
High-precision work schedule				
Regular days	4310	38.4	90.7	9.3
Regular evenings	874	8.6	89.9	10.1
Regular nights	899	9.7	91.4	8.6
Slow frequency rotating shifts	2514	20.1	92.8	7.2
Medium frequency rotating shifts	1919	15.4	91.3	8.7
Rapid frequency rotating shifts	535	4.1	86.2	13.8
Undefined frequency rotating shifts	399	3.4	87.3	12.7
Moderate-precision work schedule				
Regular days	4310	38.4	90.7	9.3
Regular evenings	874	8.6	89.9	10.1
Regular nights	899	9.7	91.4	8.6
Rotating shifts	5367	43.2	91.2	8.8
Low-precision work schedule				
Regular days	4310	38.4	90.7	9.3
Shift work (regular evenings, regular nights, or rotating shifts)	7140	61.6	91.1	8.9
Sex				
Female	10 694	94.7	91.0	9.0
Male	756	5.3	89.4	10.6
Age (years)				
<35	2131	20.5	91.5	8.5
35–44	3063	27.8	89.8	10.2
45–54	3973	34.3	90.4	9.6
55 and over	2283	17.5	93.0	7.0
Family/living situation				
Living with spouse/partner	3153	24.9	92.8	7.2
Unattached living alone	1514	13.3	88.4	11.6
Living with spouse/partner + children	4885	44.8	91.8	8.2
Other	1898	17.1	87.8	12.2
Household income[b]				
High	10 548	94.5	91.1	8.9
Low	902	5.5	87.4	12.6
Chronic health conditions[c]				
None	3693	33.9	94.7	5.3
1 or more	7757	66.1	89.0	11.0
Employment type				
Permanent, full-time	6407	56.9	91	9
Permanent, part-time	3459	31.0	90.7	9.3
Non-permanent, full-time	497	3.6	90.0	10.0
Non-permanent, part-time	1087	8.5	91.5	8.5
Scheduling flexibility[d]				
Yes	3154	27.3	92	8
No	8296	72.7	90.5	9.5

Table 1. *Continued*

	Frequency (n = 11 450)	(%)	Depression No (%)	Depression Yes (%)
Workplace type				
Hospital	5936	66.1	91.2	8.8
Long-term care facility	2879	16.3	90.1	9.9
Community	1669	10.7	90.5	9.6
Other	966	6.9	90.7	9.3
Paid overtime[e]				
Yes	3481	33.5	89.8	10.2
No	7969	66.5	91.5	8.5
Typical shift duration				
8 hours or less	7026	62.8	90.1	9.9
12 hours or more	3646	31.3	92.1	7.9
Various	778	6.0	92.9	7.1

[a]All percentages weighted to account for NSWHN probability sampling.
[b]Household Income: categories modelled after Statistics Canada methods (Shields 2002), based on two questions: 'What is your best estimate of the total income, before taxes and deductions, of all household members from all sources in the past 12 months?' and 'Number of people in the household'. 'Low household income' = (1–2 people; income <$30 000) or (3–4 people; income <$40 000) or (5+ people; income <$60 000); 'high household income' = (1–2 people; income ≥$30 000) or (3–4 people; income ≥$40 000) or (5+ people; income ≥$60,000). Note: Donor imputation was used in the NSWHN for 7% of respondents who did not state their household income (Statistics Canada 2006).
[c]Chronic health conditions: derived variable including only long-term conditions that have or are expected to last 6 months or more, and that have been diagnosed by a health professional: allergies, asthma, fibromyalgia, arthritis or rheumatism, back problems, migraine headaches, diabetes (non-pregnancy related), heart disease, cancer, stomach or intestinal ulcers, bowel disorder (such as Crohn's disease or colitis), thyroid condition, chronic fatigue syndrome, multiple chemical sensitivities. Respondents indicating yes to one or more of these conditions were assigned yes for this variable.
[d]Scheduling flexibility: based on the question 'Does your employer offer flexibility in the hours nurses can choose to work?' Respondents indicating 'No' or 'Don't know' were assigned 'no' for this variable.
[e]Paid overtime: based on the question 'How many hours of paid overtime do you usually work per week?' Respondents indicating zero hours were assigned 'no' for this variable.

the presence and strength of a relationship between work schedule and depression while adjusting for the previously stated confounders. Individual models were run for each work schedule exposure grouping (high-, moderate-, and low-precision).

Results

The distribution of study variables within the study sample (n = 11 450) is provided in Table 1. Over 60% of respondents reported something other than a regular daytime schedule. Outside of a regular day schedule (38.4% of respondents), the most frequently reported schedules were slow (20.1%) and medium (15.4%) frequency rotating shifts. Depression was observed in 9.1% of the current study sample, similar to the overall survey finding of 9.4%. Depression was most prevalent in respondents working rapid frequency rotating shifts (13.8%), and in those who reported rotating shifts but had not worked in the 2 weeks prior to the survey (12.7%).

In terms of potential confounding variables, the majority of respondents were females in the high household income category, with one or more chronic health conditions, employed in permanent full-time work, working in hospital settings, and with typical shift durations of 8 hours or less. Nearly half of respondents reported living with a spouse/partner and children. Approximately one third reported some degree of flexibility in their work hours, and working overtime every week, respectively.

Associations between the three work schedule exposure groupings and depression are presented in Table 2. Only the model using the high-precision work schedule grouping showed strong associations between work schedule and depression. In this model, the adjusted OR for depression was increased in the rapid rotating shifts category (OR = 1.51, 95% CI = 0.91–2.51) and in the undefined rotating shifts category (OR = 1.67, CI = 0.92–3.02), while it was decreased in the slow rotating shifts category (OR = 0.79, 95% CI = 0.57–1.08). No strong relationships emerged between work schedule and depression (OR range 0.95–0.99; Table 2) in the adjusted models using the moderate- and low-precision work schedule groupings.

For the other potentially confounding variables, only the shift duration variable produced a substantial

shift in the work schedule point estimates when added to the unadjusted high-precision work schedule model. In adjusted models, the strongest relationships with depression were observed in the 35 to 44 year age category (relative to 55 years and over age category); in unattached individuals living alone and those with 'other' family/living circumstances (relative to those living with a spouse or partner); and in those reporting one or more diagnosed chronic health conditions (relative to those reporting no diagnosed chronic health conditions). Increased ORs for depression were also observed for other younger age categories, for males, for those with low household incomes, for those with shorter (8 hours or less) shift duration, for those working some weekly paid overtime, and for those reporting no scheduling flexibility. These relationships were consistent across all models (low-, moderate-, and high-precision exposure groupings).

Discussion

The NSWHN, 2005 (Statistics Canada 2006) is a nationally representative Canadian cross-sectional survey that collected a wealth of information on work scheduling, workplace characteristics, and health variables compared to many other large-scale surveys. Importantly, it also collected information on frequency of shift rotations, an exposure characteristic that to our knowledge has not been described in other studies of shift work and health.

The high precision work schedule exposure grouping used in this study divided the sample into seven work schedule categories: regular day (38.4%), regular evening (8.6%), regular night (9.7%), and rotating shift work based on shift changes in the past 2 weeks: 0 to 1 (20.1%), 2 to 3 (15.4%), 4 or more (4.1%), and undefined (3.4%). For the moderate-precision work schedule exposure grouping, the rotating shift work categories were aggregated to form one rotating category that represented 43% of the total sample. For the low-precision work schedule exposure grouping, all categories of non-regular daytime work were further aggregated into one shift work category that represented 61.6% of the total sample.

As hypothesized, the strongest relationships between work schedule and depression were observed in the high-precision work schedule exposure grouping model that considered elements of shift timing and rotation frequency. The OR for depression was increased in the rapid frequency rotating shifts and the undefined frequency rotating shifts categories, and decreased in the slow frequency rotating shifts category. No relationship was observed with depression for the low- and moderate-precision work schedule exposure groupings.

The estimates for the high-precision work schedule exposure grouping categories in the adjusted model had 95% CIs that included the OR value of '1'. It is worth noting that bootstrapping provides a more accurate indication of the amount of random error in the point estimates, and that CIs are intended to serve as a general guide to the amount of random error in the data rather than as a literal measure (Rothman 2002). The point estimates presented for the high-precision work schedule model are stronger than those obtained for the medium- and low-precision models. ORs close to '1' were noted in the moderate-precision work schedule exposure grouping model that considered elements of shift timing only, and in the low-precision work schedule exposure grouping model that dichotomized shift work exposure into yes/no categories. The observed elevated odds for depression for the work schedule variable in the high-precision exposure grouping model persisted after adjustment for confounders.

The elevated OR for depression in this study's rapid rotating shifts category is a new finding, but consistent with reports from other emerging research. Rapidly rotating shifts may reflect precarious employment situations (work involving temporary, contract, or casual on-call positions that often lack benefits and job security; also referred to as "casual", "seasonal", "temporary", "non-standard", or "contingent" work; Quinlan *et al.* 2001). Workers in precarious employment often experience unexpected changes in work schedule with little advance notice (Lewchuk *et al.* 2015), which has been linked to negative social effects (Åkerstedt and Kecklund 2017). Precarious employment and job insecurity in general are associated with a number of related detriments (Quinlan *et al.* 2001), including increased social disruption, stress, and depressive symptoms (Burgard *et al.* 2009; Lewchuk and Lafleche 2017).

Rapidly rotating shifts are also likely to increase the likelihood of quick returns, where 11 hours or less of free time is scheduled between shifts (Council of the European Union EP 2003). Some shift workers view quick returns as being more problematic than night work (Åkerstedt and Kecklund 2017); with recent evidence showing that quick returns have negative effects on sleep and fatigue (Eldevik *et al.* 2013; Flo *et al.* 2014; Dahlgren *et al.* 2016) and increase the risk of sick leave (Vedaa *et al.* 2017). In these studies (Eldevik *et al.* 2013; Flo *et al.* 2014; Dahlgren *et al.* 2016; Vedaa *et al.* 2017), the negative effects of quick returns were greater than those of night work.

Table 2. Unadjusted and adjusted logistic regression odds ratios (ORs) and confidence intervals (CIs) modeling depression = yes, National Survey of the Work and Health of Nurses, 2005.

	Unadjusted OR	95% CI		Adjusted OR[a]	95% CI	
High-precision work schedule grouping						
Schedule						
Regular days	Ref			Ref		
Regular evenings	1.09	1.03	1.15	**1.00**	0.70	1.43
Regular nights	0.91	0.86	0.96	**0.96**	0.63	1.45
Slow frequency rotating	0.75	0.72	0.79	**0.79**	0.57	1.08
Medium frequency rotating	0.92	0.88	0.97	**1.00**	0.71	1.40
Rapid frequency rotating	1.55	1.45	1.66	**1.51**	0.91	2.51
Undefined frequency rotating	1.42	1.31	1.53	**1.67**	0.92	3.02
Sex						
Female				Ref		
Male				1.28	0.84	1.96
Age group						
55 and over				Ref		
45–54				1.50	1.09	2.06
35–44				1.77	1.27	2.46
<35				1.42	0.98	2.05
Family/living situation						
Living with spouse/partner				Ref		
Unattached living alone				1.66	1.16	2.38
Living with spouse/partner + children				1.00	0.74	1.33
Other				1.62	1.19	2.20
Household income						
High				Ref		
Low				1.30	0.95	1.76
Chronic health conditions						
None				Ref		
1 or more				2.29	1.74	3.00
Employment type						
Permanent, full-time				Ref		
Permanent, part-time				1.10	0.86	1.41
Non-permanent, full-time				1.04	0.56	1.92
Non-permanent, part-time				1.06	0.72	1.55
Scheduling flexibility						
Yes				Ref		
No				1.19	0.92	1.53
Workplace type						
Hospital				Ref		
Long-term care facility				1.08	0.84	1.38
Community				1.10	0.79	1.53
Other				1.17	0.76	1.78
Paid overtime						
No				Ref		
Yes				1.20	0.95	1.52
Typical shift duration						
12 hours or more				Ref		
8 hours or less				1.29	0.98	1.69
Various				0.87	0.52	1.44
Moderate-precision work schedule grouping						

Table 2. *Continued*

	Unadjusted OR	95% CI		Adjusted OR[a]	95% CI	
Schedule						
Regular days	Ref			Ref		
Regular evenings	1.09	1.03	1.15	0.99	0.69	1.42
Regular nights	0.91	0.86	0.96	0.95	0.63	1.44
Rotating shifts	0.93	0.90	0.96	0.99	0.75	1.29
Low-precision work schedule grouping						
Schedule						
Day worker	Ref			Ref		
Shift worker	0.95	0.92	0.98	0.98	0.77	1.25

[a]Models adjusted for sex, age, living/family situation, household income, chronic health conditions, employment type, scheduling flexibility, workplace type, paid overtime, and typical shift duration.

The preceding evidence on quick returns could explain the lack of strong relationships noted between regular night shift work and depression in this study. A strong body of evidence indicates that night work is linked to increased risks of circadian disruption and negative health outcomes (Haus and Smolensky 2006; International Agency for Research on Cancer 2010), and some studies have noted associations between regular night shifts and depressive outcomes (Bara and Arber 2009; Moon *et al.* 2015). However, it is possible that social issues related to rapidly rotating shift schedules represent an equally strong (or stronger) link to negative mental health outcomes in shift workers compared to circadian disruption associated with night work. Rapidly rotating schedules may impose a greater mental strain on workers than regular night work, particularly in cases of irregular work schedules. In Canadian workers for example, dissatisfaction with work-life balance is most pronounced in shift workers reporting split, on call or casual, or irregular schedules (Williams 2008). This could also explain the decreased OR for depression noted in the slow frequency rotating shift schedule category; rare or occasional changes in shift timing (0 to 2 times per month) are likely to be more predictable and may even confer greater work-life balance relative to regular daytime workers.

The increased OR for depression in the undefined frequency rotating shifts category (individuals not working in the 2 weeks prior to survey) is not straightforward to interpret. Depression is associated with temporary work leave and work impairment (Gilmour and Patten 2007; Lim *et al.* 2008), so one explanation for an increased OR for depression is that depression status (unrelated to work schedule) resulted in work absence in this group. Another possibility is that the characteristics of workers' rotating schedules (e.g. high frequency rotations and associated stressors) resulted in depression and sick leave (Driesen *et al.* 2011). Since the NSWHN's cross-sectional design lacks the temporal detail needed to assess which scenario is most likely, this study's finding of increased depression in nurses with undefined rotating shifts should be interpreted with caution.

Most prior studies into shift work's effects on mental health have utilized exposure groupings that are either dichotomous (Bara and Arber 2009; Driesen *et al.* 2011) or incorporate considerations of shift timing only (Geiger-brown *et al.* 2004; Berthelsen *et al.* 2015; Moon *et al.* 2015), without consideration of shift rotation frequency. The low precision of exposure groupings used in these studies is one plausible explanation for inconsistencies in observed findings. A British household panel survey found that working varied shifts was related to increased risks of anxiety/depression and minor mental disorders in females over time, but years' duration of night work did not show strong effects for these outcomes, whereas for males, years' duration of night shifts, but not varied shifts, increased risk of anxiety/depression and minor mental disorders over time (Bara and Arber 2009). Another prospective cohort study found an increased risk of depressive disorder in current or former female shift workers versus never shift workers in adjusted analyses; no strong relationships were noted in current or former male shift workers (Driesen *et al.* 2011). A short prospective cohort study of nurses found no strong relationships between working nights and working rotating shifts and independent measures of anxiety and depression (Berthelsen *et al.* 2015). In terms of cross-sectional research, a study of hotel workers observed an elevated risk of depression in all shift worker categories relative to regular day workers (Moon

et al. 2015). In another small cross-sectional study of nursing assistants, regular evening, and rotating shift work was associated with an increased risk of depressive disorder, whereas night work showed a protective effect (with all CIs spanning '1'; Geiger-brown *et al.* 2004).

In addition to precise and hypothesis-driven exposure assessment and assignment, the accurate estimation of exposure–response relationships relies on the control of variables that may confound the relationship between primary exposure and outcome. In this study's multivariable models, the observed relationships between work schedule and depression persisted after adjustment for a number of known and potential confounders available in the NSWHN. The relationships observed between these confounders and depression are consistent with a body of research that has found higher rates of depression among younger adults (Gilmour and Patten 2007; Ferrari *et al.* 2013), single or previously married individuals (Gilmour and Patten 2007), low income earners (Gilmour and Patten 2007), and those with chronic health conditions (Patten *et al.* 2005; Gilmour and Patten 2007). Low control over work time (relating to low scheduling flexibility; Nijp *et al.* 2012), long working hours (relating to overtime; Virtanen *et al.* 2011), and shorter shift durations (Lowden *et al.* 1998) have also been linked to negative mental health outcomes. Overall, the observed relationships between the confounders and depression provide face validity for the models and the main findings in the current study.

To reduce the likelihood of exposure misclassification, this study's analyses were restricted to individuals working one nursing job, since work schedule information was collected for respondents' 'main nursing job' only. However, this study's work schedule categories do retain some degree of misclassification, since the NSWHN does not differentiate between rotating shift work involving nights versus rotating shift work that involves only days and evenings. Furthermore, the NSWHN does not capture other exposure characteristics such as direction of shift rotations (Barton and Folkard 1993), history of shift work, and individual morning/evening preference (Erren and Morfeld 2014) that may be important to consider when assessing the impacts of work schedule on depression. The current study's findings support the importance of assigning detailed work schedule categories to identify effects where they exist, and justify the need to collect detailed data on work schedule characteristics in future studies.

The relatively homogenous nature of NSWHN respondents reduced sources of residual confounding that are often present in general population surveys, such as differences in work environments and tasks that may impact on depressive outcomes (Theorell *et al.* 2014). The NSWHN's size also permitted the restriction of analyses to nurses working in direct care areas, further reducing unmeasured differences in exposures between comparison groups and the potential for a biased assessment of the relationship between work schedule and depression. Although useful for the purpose of these analyses, the sample's homogeneity does introduce the possibility that the findings do not apply to other occupations and work environments, where the type and timing of work demands may have different impacts on depression.

A widely acknowledged challenge in shift work research is the self-selection of individuals into and out of shift work (the 'healthy worker effect') leading to a workforce of shift workers that is healthier than day workers (Knutsson 2004) and biasing results towards the null. While self-selection 'into' shift work (primary selection) may be less of a problem in nurses since most direct care areas require some degree of night work, particularly for new graduates, self-selection 'out of' shift work (secondary selection) is likely a bigger issue affecting this study sample. Recent longitudinal studies have shown that the presence of depressive symptoms (Driesen *et al.* 2011) and other depression-related outcomes (Waage *et al.* 2014) at baseline is associated with a change in work schedule (leaving night work). The NSWHN's cross-sectional design and lack of information on work schedule history did not allow for a temporal assessment of self-selection effects, and it is certain that some amount of misclassification was present in the 'day worker' category, where some former shift workers would be classified as day workers. Depressed workers who had previously moved from shift work (rapidly rotating or otherwise) into a regular day schedule could have diluted the reference category and produced attenuated associations. Despite this, a relationship between work schedule and depression was observed when the high-precision exposure grouping was used. It seems unlikely that depressed individuals would differentially move into more disruptive schedules (i.e. rapidly rotating shift work) that would be required to overestimate the strength of association between work schedule and depression in this category of workers. Further, the assessment of a short-latency health outcome may have minimized the effects of self-selection out of shift work at the time of survey.

This study's exposure measures are based on self-reports that were not validated against objective data. However, the validity of self-reported shift work exposure was recently examined in a Finnish study that compared self-reports to payroll registry data (Härmä *et al.*

2017). Self-reported work involving night shifts (regular and rotating) showed greater sensitivity and specificity than shift work not involving nights; imprecise reports of shift work not involving nights (e.g. individuals that rotated between day and evening shifts identifying themselves as day workers) resulted in a bias towards the null when assessing work schedule's effects on fatigue (Härmä *et al.* 2017). In the NSWHN, the type of rotating shift work (involving nights versus no nights) was not differentiated. Since the majority of respondents (62.8%) in the current study indicated 8-hour shift duration, rotations between day and evening shifts without any night shift work likely occurred in a (unknown) number of workers, and may have produced a bias towards the null when assessing relationships between shift work schedule and depression.

Concerning the validity of the outcome measure, social desirability bias (arising from the stigma attached to mental illness) may have produced an underreporting of depressive symptoms. This bias was noted in another large general population health survey conducted in Canada (O'Donnell *et al.* 2016), although this would likely be non-differential across shift type and would therefore exert a conservative bias on the exposure–response relationship.

Data collection for the NSWHN was conducted over a decade ago, however, this survey remains the largest and most detailed source of information on work and health characteristics at the occupational level, in one of Canada's largest working populations. The use of this data source to investigate relationships between shiftwork and depression still holds relevance today, since the hypothesized relationships are temporally consistent, and since the investigation of precision in exposure assessment remains a current issue. This study's findings are also relevant elsewhere, given the elevated prevalence of depression and other measures of psychological morbidity observed in nursing populations outside of Canada, such as the USA and the UK (Stansfeld *et al.* 1999; Letvak *et al.* 2012).

Conclusions

As with other areas of shift work epidemiology, the quality of evidence linking work schedule to depression has been challenged by the use of coarse exposure assessment and assignment that cannot adequately characterize important aspects of shift work exposure. While this study, based on a cross-sectional survey, is not a 'best case example' of exposure assessment, our results highlight some important concepts to bear in mind for future research. The high-precision work schedule exposure grouping used in this study, that incorporated considerations of both shift timing and frequency of shift rotations, is an improvement over groupings used in many other studies of shift workers. This definition reduced within-group heterogeneity compared to the low- and moderate-precision categories and resulted in the strongest associations with depression in this sample of nurses. Our study's findings support the need to consider and collect the data needed for precise and conceptually driven exposure assignment in future studies of shift work and health. This will help to correctly identify exposure–response relationships within individual studies, to facilitate comparability between studies, and to appropriately target health interventions. Further research into the effects of shift rotation frequency on depression is also recommended.

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