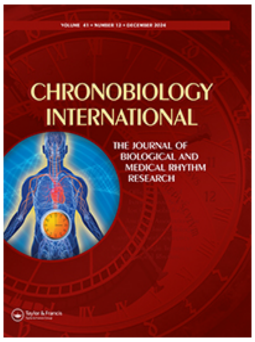

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ORIGINAL ARTICLE

The association between vigour and flexibility with injury and alertness during shift work

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ABSTRACT
Models of shift work and health suggest that individual differences in circadian rhythm characteristics may moderate the relationship between night shift work and injury, but this argument has not been directly tested. In this study, we tested the efficacy of two circadian rhythm characteristics—vigour and flexibility—as moderators of the path between shift work and injury. In addition, we aimed to replicate the association between vigour, flexibility, and alertness by time of day, and the measurement properties of the Circadian Type Inventory. We recruited 401 healthcare workers from Australia and Great Britain. After controlling for confounding variables, the results showed that vigour moderated the association between shift work and injury. Participants with values of vigour at the mean ($\beta = 0.5120$, $p < 0.0013$, 95% CI = [0.2018, 0.8223) and one standard deviation below the mean ($\beta = 0.9048$, $p < 0.0001$, 95% CI = [0.4648, 1.3447] reported significantly more injuries. No moderation was found for flexibility. Significant differences in alertness by time of day were observed in participants with higher levels of vigour compared to lower levels of vigour. No differences in alertness were observed for the flexibility scale. These results indicate that vigour may be a robust indicator of shift work tolerance. We replicated the posited two-factor structure of the Circadian Type Inventory, found the scales to have good reliability, and established for the first time, criterion-related validity for the vigour scale.

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Amplitude; Chronotype; injury; languid; shift work; vigour

Introduction

Shift work schedules vary on several parameters, such as shift length, shift start and end time, and whether shifts are fixed or rotate continuously (Ferguson et al. 2023). As a result of this complexity, the literature considers shift work that includes night work, to be a working arrangement outside of 09:00–18:00 (Costa 2003) that also includes at least three hours of work between 23:00 and 06:00 (Garde et al. 2019). The prevalence of shift work is approximately 15% in Australia (Australian Bureau of Statistics 2022), 21% in the European Union (Eurofound 2017), and 16% in the United States (US Bureau of Labor Statistics 2023). These estimates, however, mask the prevalence of shift work estimated at 50% in occupations such as nursing (Querstret et al. 2020).

The literature consistently shows that shift work is associated with several physical and psychological impairments. The International Agency for Research on Cancer classified "shift work that involves circadian disruption" as a probable human carcinogen (Stevens et al. 2011), and recent data concluded that shift work, regardless of whether night work is involved was associated with an increased risk of breast cancer for women over 50 years of age (Härmä et al. 2023). Torquati et al. (2018) reviewed 21 studies and concluded that cardiovascular events were 17% more common among rotating shift workers than in day workers. In addition, a dose–response relationship was identified such that the cardiovascular risk became evident after five years. Drawing on 36 939 participants, Yang et al. (2022) focused on the presence of cardiometabolic multimorbidity, the simultaneous existence of hypertension, diabetes, coronary heart disease and stroke. Their results indicated that night workers had a 16% greater risk of cardiometabolic multimorbidity than day workers, and a dose–response relationship was also identified. Shift work sleep disorder (SWD) is characterized by excessive sleepiness and insomnia attributed to work hours. The literature suggests that the prevalence of SWD is 32% among night workers and the main predictors are working nights, working long weekly hours and short sleep duration (Di Milia, Pallesen et al. 2013). The literature has dependably shown that shift work involving night work is associated with sleep loss and higher levels of

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sleepiness and fatigue (Sallinen and Kecklund 2010). Working at night places additional strain on workers due to circadian disruption and the accumulation of sleep loss (Härmä et al. 2015).

Circadian rhythms refer to the constant 24-hour oscillations in psychological and physiological (Hood and Amir 2017) functions such as body temperature, sleep, and alertness. Circadian rhythms can be easily assessed using self-report tools given that they are non-invasive, quickly administered, and many of these tools have good reliability and validity (Adan et al. 2012; Di Milia, Adan et al. 2013). Circadian rhythms can be described in terms of three core characteristics. A comprehensive review of the literature noted that *morningness* or the phase of the rhythm has attracted most of the research focus (Adan et al. 2012), and this emphasis remains. In contrast, the *amplitude* and *stability* of the rhythm are less studied.

The Circadian Type Inventory (CTI) (Di Milia et al. 2005; Folkard et al. 1979) comprises of two scales developed for the purpose of assessing rhythm amplitude and stability. The scales can be considered to reflect on Borbély's (1982, 2022) two-process model of sleep regulation. The model proposes that sleep is driven by a circadian process (or Process C) and a homeostatic process (Process S) that increases the need for sleep as wakefulness increases. The construct "flexible-rigid" refers to the flexibility of sleeping habits and is considered to be a proxy for the amplitude of Process C; the argument is that a lower amplitude process C (flexible) is better suited for night work compared with a high amplitude referred to as "rigid" types. Rigid types reported difficulty in falling asleep early, sleeping in, and found it difficult to sleep at unusual times (Folkard et al. 1979). The second indicator, "vigorous-languid," describes the ability to increase alertness above the levels of alertness produced by Process C. Vigorous-languid is an indicator of arousability and may be related to the strength of the nervous system (Gray 1967). Vigorous types were better able to cope with sleep loss and to wake easily at unusual times and potentially this allows for better adjustment to night work (Folkard et al. 1979). For clarity, we will refer to the two constructs as flexibility and vigour respectively. Flexibility and vigour may be considered as biological traits given, they are underpinned by the circadian variation in Process C and the nervous system. The measurement properties of the CTI are sound. The scale reliabilities are in the order of 0.75, the test-retest reliability over a three-month period was 0.72 for the vigour scale and 0.75 for the flexibility scale (Di Milia et al. 2005), and recent evidence reported that the factor structure was stable over an eight-year period in a large Norwegian sample (Pallesen et al. 2021).

There is emerging literature suggesting the efficacy of vigour and flexibility in facilitating adjustment to shift work. Vigorous types are reported to be more alert in the early morning hours and need less sleep to feel refreshed, while flexible types are also more alert than rigid types across the day (Di Milia et al. 2005). Several cross-sectional and longitudinal studies of shift-working nurses have reported that lower levels of vigour are associated with SWD (Chen et al. 2020; Flo et al. 2012) and is more prevalent in patients with bipolar disorder (Boudebesse et al. 2013). In a random population sample, vigorous and flexible types were associated with better resilience, coping and required less sleep (Di Milia and Folkard 2021). An earlier review of the shift work tolerance literature concluded that vigour and flexibility were among the best protective factors for shift work tolerance (Saksvik et al. 2011), and this conclusion was supported in a recent review (Degenfellner et al. 2021).

There are several models of shift work and health that suggest individual differences in circadian rhythm function may act as moderators of the relationship between shift work and health (Barton et al. 1995; Smith et al. 1999). Surprisingly, we found only one study that tested the role of morningness as a moderator. Barnes-Farrell et al. (2023) reported that night workers suffer more psychosocial strain when their preference for cognitive activity is misaligned with their phase preference, whereas no differences in strain are observed among day workers. We did not find any studies that employed vigour and flexibility as moderator variables, but many studies have used these constructs as predictor variables (Barton et al. 1995; Chen et al. 2020; Flo et al. 2012; Smith et al. 1999).

We aim to make three main contributions to the literature. First, we advance the literature by testing the role of vigour and flexibility as moderators of the relationship between shift work and injury. We chose injury as the dependent variable because our sample of healthcare workers included mostly nurses, and nursing is a profession associated with shift work, and many workplace hazards. Dressner and Kissinger (2018) estimated that registered nurses in the American private sector had a minimum of 19, 790 nonfatal injuries in a one-year period that required at least a day's absence from work. "Sharps" injuries refer to instruments that result in cutting or pricking (Health and Safety Executive 2021), and a review of 87 studies across 31 countries estimated the prevalence of needle-stick injuries at approximately 45% (Bouya et al. 2020). Furthermore, the risk of injury may be greater for self-paced work on night shift (Smith et al. 1994), and nursing is primarily self-paced work. An extension of the first contribution is that in establishing the moderating role of vigour and flexibility, we aim to establish for the first-time criterion-related validity for the RCTI (Di Milia et al. 2005). Second, we revisit preliminary findings that vigour and flexibility are associated with greater alertness by time of day (Di Milia et al. 2005). Finally, we aim to confirm the posited two-factor model of the RCTI in this sample. To be of value, self-reported measurement tools must demonstrate sound indicators of reliability and validity.

Methods

The study employed a cross-sectional design. A convenience sample of approximately five hundred Australian and five hundred British participants working in hospital settings received a package from their supervisors that included an invitation letter and the survey tool. The invitation letter outlined the aim of the study and highlighted that participation was voluntary, anonymous, and that participants could cease participation at any time. Participants provided written informed consent before completing the survey. The study complied with the Declaration of Helsinki, and the data were collected in accordance with the approval provided by the Human Ethics Committee at Central Queensland University (H05/11-119).

Measures

The survey collected demographic data and the following variables:

Work schedule. The variable was based on self-reported shift start and end times for day, evening, and night shifts on their current schedule. We used this information to create two groups. The "day" group consisted of employees who mostly began their shift between 07:00 and 08:00 and included 18 participants who worked day and afternoon/evening shifts. Evening shifts commenced between 14:00 and 15:00; evening work is not associated with circadian disruption (Härmä et al. 2015). The "shift work" group worked a rotating day, afternoon, and night shift system. Night shifts commenced at approximately 22:00 and 23:00.

Work hours. This variable is the sum of individuals' normal work hours and any additional paid hours.

Circadian Type Inventory. The CTI (Di Milia et al. 2005) comprises two scales. The languid-vigour scale has 6-items and represents rhythm amplitude. In contrast to former studies, we (reverse) scored the items such that high scores indicate vigour. A sample item is *"Do you tend to need more sleep than other people?."* The rigid-flexible scale has 5-items that represent rhythm stability. High scores indicate flexibility. A sample item is *"Do you find it easy to work late at night as earlier in the day?."* Responses were made on a five-point scale (1 = almost never, 5 = almost always).

Karolinska Sleepiness Scale (KSS). The KSS (Åkerstedt and Gillberg 1990) uses a nine-point rating scale. We labelled the anchors as follows: 1 = very sleepy and 9 = very alert.

Job Satisfaction. This variable was based on two items from Ganzach's (2003) broader job satisfaction scale. A sample item is *"How would you rate your satisfaction with the organization?."* Responses were made on a four-point scale (1 = very dissatisfied, 4 = very satisfied).

Injury. We used a 3-item measure developed by Probst and Brubaker (2001). Participants reported the number of minor, major (lost time injury) and "near" accidents they had experienced in the previous 12 months. We added the responses across these categories to calculate a total score.

Control variables. Age and sex are associated with changes in circadian rhythm function (Fischer et al. 2017) We also control for "nation" because there may be unknown differences in work characteristics between the two samples; and job satisfaction, given some findings, suggests that satisfaction with the work schedule assists with recovery time (Garraio et al. 2023).

Data Analyses

Data were checked to ensure that the variables were normally distributed prior to the analyses. All variables were within accepted tolerances for skew and kurtosis of ±1 standard deviation except for the injury variable. Injury data are rare events and thus, positively skewed (Probst and Brubaker 2001). The mean number of injuries was 4.99 (SD = 8.96) across the three categories, skew was 3.28, and kurtosis was 12.87. We transformed the injury variable using the square root of the distribution and this procedure produced a mean of 1.53 (SD = 1.63), skew of 1.19 and kurtosis was 1.40. Minor injuries were most common ($M = 3.56$, SD = 7.04), followed by "near" accidents ($M = 1.35$, SD = 4.26), and major injuries ($M = 0.09$, SD = 0.36).

SPSS (V28.0) was used for the data analyses and PROCESS macro for SPSS (V4.2; Hayes 2022) using 95% confidence intervals and bootstrapping based on 5000 samples to test for moderation. We then conducted two separate stepwise hierarchical regression to further assess the associations. First, we entered the control variables at step one, followed by the appropriate CTI construct and the work schedule at step two.

The final step included the interaction between CTI construct and the work schedule.

To test for differences in alertness on the vigour and flexibility scales, we created two groups using the 30th and 70th percentiles of each distribution. These percentiles were chosen to compare the extreme scores on each scale. Thus, we created a languid and a vigour group, and a rigid and flexible group. We then used multivariate generalized linear models to test for differences in alertness while controlling for the influence of age and sex. Confirmatory factor analysis (AMOS V28) of the CTI (Di Milia et al. 2005) was conducted using structural equation modelling with a 50% random sample ($n = 210$) to account for the chi-square statistic being sensitive to large samples (Babyak and Green 2010).

We also test for common method variance in the data; the notion that the associations between the variables are inflated because the data are collected using the same method (Podsakoff et al. 2003). Values over 50% are considered problematic (Podsakoff et al. 2003).

Results

Participants

We received 401 responses (213 from Australia and 188 from Britain (response rate = 40.10%) from participants who worked at least 20 hours per week. We identified 177-day workers (45%) and 216 shift workers. Approximately 54% of the Australian sample, and 56% of the British sample were shift workers. Approximately 70% of participants identified as nurses, and the others were a mix of allied health professionals and administrators.

The overall mean age was 41 years (SD = 11.02). The Australian sample ($M = 42.12$, SD = 10.96) was significantly older than the British sample ($M = 39.73$, SD = 11.01), but the effect size was small (Cohen's $d = 0.22$). Day workers were significantly older ($M = 42.61$, SD = 11.25) than the shift work group ($M = 39.83$, SD = 10.70); the effect size was small (Cohen's $d = 0.25$).

Both samples were dominated by females (82%), and the proportion of females was similar in both samples. The majority (66%) were partnered, and the balance were single or widowed. The mean time in the healthcare sector was 17.57 years (SD = 11.28). The mean working hours were 36.77 hours (SD = 8.20) in the day group and 37.31 hours (SD = 7.47) in the shift work group; these hours were not significantly different.

Descriptive Statistics

There were no significant differences between the two countries in terms of the variables of interest; therefore, we show the overall descriptive statistics in Table 1. As expected, vigour and flexibility were not correlated ($r = 0.07$). Age was negatively and significantly correlated with job satisfaction and injury. Vigour was positively correlated with age and negatively correlated with injury, while flexibility was positively linked with job satisfaction.

Moderation and Regression Results

The results suggested an interaction effect between vigour and injury ($F = 6.27$, $p < 0.05$), and a significant effect was detected for values at the mean ($\beta = 0.5120$, $p < 0.0013$, 95% CI = [0.2018, 0.8223) and one standard deviation below the mean for vigour ($\beta = 0.9048$, $p < 0.0001$, 95% CI = [0.4648, 1.3447]. This finding suggested that lower levels of vigour (languid) are associated with more injuries. No moderation was found for flexibility.

The results from the hierarchical regression analyses can be found in Table 2. The interaction effect between work schedule and vigour was significantly associated with injury ($\beta = -0.09$, $p < 0.01$), and higher levels of vigour resulted in less injury in the shift work group (see Figure 1). There was no interaction between work schedule and flexibility (see Table 3).

Alertness

A significant difference was obtained between the languid ($n = 71$) and vigour groups ($n = 61$) (Pillai's trace $F(10, 119) = 4.42$ ($p < 0.001$, $\eta^2 = .27$). The vigour group was significantly more alert from 06:00 to

Table 1. Descriptive statistics, correlations, and cronbach alpha (diagonal).

	Mean	SD	1	2	3	4	5	
1. Age	41.00	11.02	–					
2. Work hours	37.02	7.88	−0.03	–				
3. Job Satisfaction	2.76	0.66	−0.11*	−0.11	(0.73)			
4. Injury	1.53	1.63	−0.20**	0.06	−0.18**	–		
5. Vigour	18.24	4.39	0.24**	−0.03	0.03	−0.20**	(0.74)	
6. Flexibility	14.01	3.91	−0.09	0.19	0.13**	0.08	0.07	(0.74)

n = 401

*$p < 0.05$, **$p < 0.01$.

Table 2. Hierarchical regression results – work schedule and vigour predicting injury (unstandardised coefficients).

	Step 1		Step 2		Step 3	
	β	*SE*	*β*	*SE*	*β*	*SE*
Gender	−.10	.21	−.04	.21	−.06	.21
Age	−.03***	.01	−.03***	.01	−.03***	.01
Nation	.02	.05	.03	.05	.03	.05
Job satisfaction	−.47***	.12	−.47***	.12	−.48***	.12
Vigour			−.05**	.02	−.01	.03
Work Schedule ~			.51**	.16	2.14**	.67
Vigour X work schedule					−.09*	.04
R^2	.09***		.13***		.14**	
Δ R^2			.04***		.01**	

n = 401
**p* < 0.05, ***p* < 0.01, ****p* < 0.001, ~ day work (0), shift work (1).

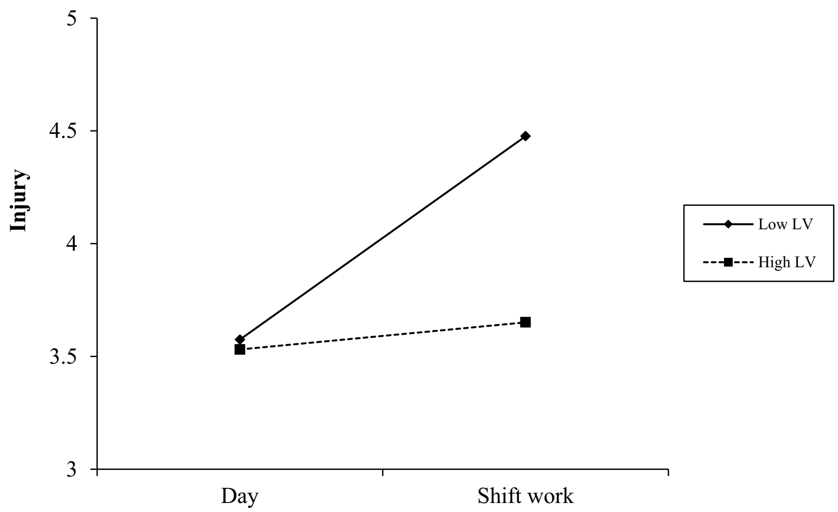

Figure 1. Moderating effect of vigour on the relationship between work schedule and injury. LV = Languid – Vigour; "Low LV" represents languid; "High LV" represents vigour.

Table 3. Hierarchical regression results – work schedule and flexibility predicting injury (unstandardised coefficients).

	Step 1		Step 2		Step 3	
	β	*SE*	*β*	*SE*	*β*	*SE*
Gender	−.12	.21	−.12	.21	−.12	.21
Age	−.03***	.01	−.03***	.01	−.03***	.01
Nation	.02	.05	.02	.05	.02	.05
Job satisfaction	−.47***	.12	−.49***	.12	−.49***	.12
Flexibility			.02	.02	.02	.03
Work Schedule ~			.50**	.16	.44	.60
Flexibility X work schedule					.01	.04
R^2	.09***		.12***		.12	
Δ R^2			.03***		.01	

n = 401
**p* < 0.05, ***p* < 0.01, ****p* < 0.001, ~ day work (0), shift work (1).

noon and then from 18:00 to 20:00 (see Figure 2). A non-significant trend suggesting that the flexible group was more alert from noon can be seen in Figure 3. We excluded alertness ratings at 02:00 and 04:00 because their inclusion reduced the sample size for these analyses. We repeated the analyses using all data and found the same pattern of results.

Confirmatory Factor Analysis

The results from confirmatory factor analyses supported the posited two-factor model to be a close fit in the sample. Several incremental fit indices indicated the robustness of the model fit (Hu and Bentler 1999) compared to the single-factor model (see Table 4). Factor

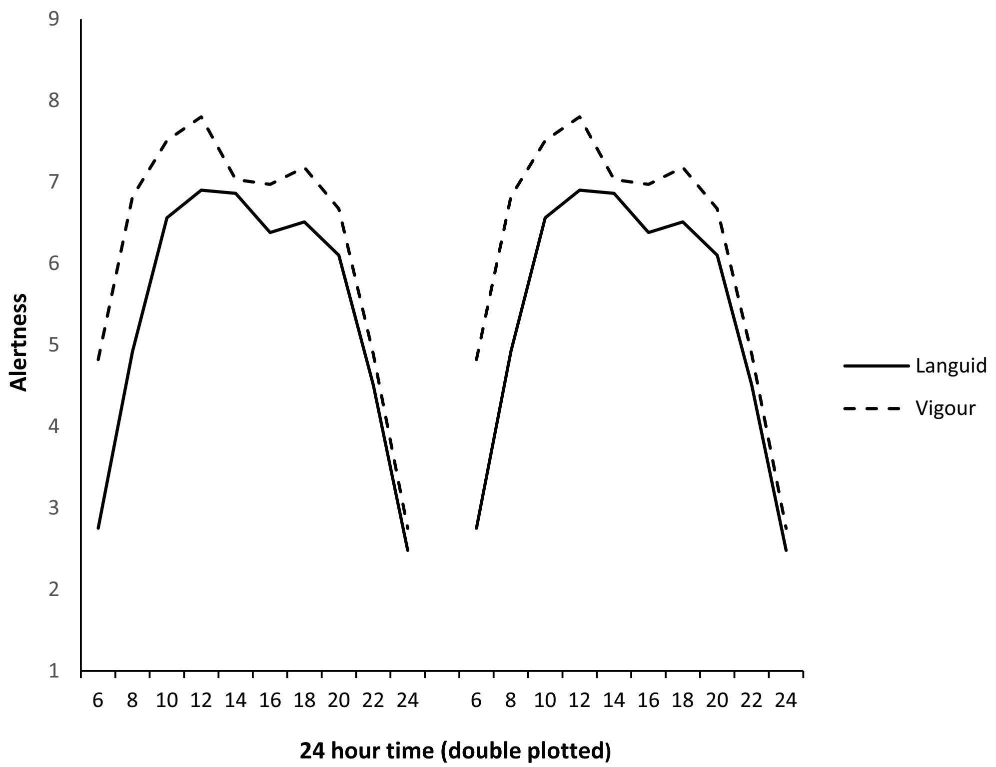

Figure 2. Alertness ratings by time of day between languid ($n = 71$) and vigorous ($n = 61$) types. Alertness scale; 1 = very sleepy; 9 = very alert.

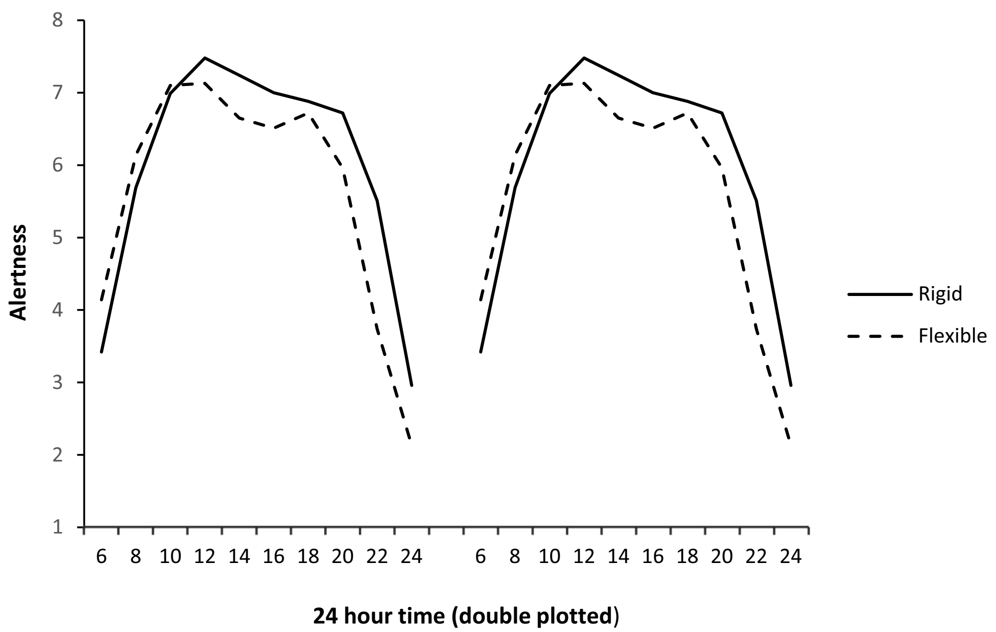

Figure 3. Alertness ratings by time of day between rigid ($n = 49$) and flexible ($n = 66$) types. Alertness scale; 1 = very sleepy; 9 = very alert.

Table 4. Confirmatory factor analysis of the circadian type inventory.

Model	χ^2	df	χ^2/df	CFI	TLI	RMSEA	SRMR
Posited two-factor model	78.69	42	1.874	0.93	0.91	0.065	0.083
Single-factor model	300.49	44	6.829	0.49	0.36	0.167	0.167

n = 210

χ2 – chi-square, df – degrees of freedom, CFI – comparative fit index, TLI – Tucker-Lewis index, RMSEA – root mean square error of approximation, SRMR – standardised root mean square residual..

analyses indicated that the vigour scale explained 27% of the variance and flexibility scale explained 22%. The item factor loadings across the two scales ranged from 0.47–0.81. Cronbach's alpha for both scales was 0.74.

We tested for common method variance using Harman's single-factor test. The amount of variance explained was 17%.

Discussion

Our goals were to advance the literature by making three contributions: a) testing the moderating role of vigour and flexibility in the path between shift work and injury, b) examine the proposed relationship between vigour and flexibility, and alertness, and c) assess the measurement properties of the CTI (Di Milia et al. 2005). We discuss these contributions, the limitations of our findings and make some recommendations for future studies.

Models of shift work and health (Barton et al. 1995; Smith et al. 1999) propose that individual differences act as moderators of this relationship. Our study is unique given it is the first to examine the role of vigour and flexibility as moderators of the relationship. We found evidence to suggest that vigour but not flexibility acted as a moderator. The second contribution was to revisit earlier findings that vigour and flexibility were associated with greater alertness by time of day. Our results supported the proposition that vigorous, but not flexible types were more alert in the morning.

The literature routinely reports that working at night is problematic due to circadian disruption, the accumulation of sleep loss, greater sleepiness and fatigue (Härmä et al. 2015). The finding that vigorous types reported fewer injuries and greater alertness provides support for Folkard et al. (1979) argument that vigorous types are better able to increase alertness above the rhythmic oscillation of the circadian rhythm, or Process C (Borbély 1982). While we did not obtain sleep data to further assess this argument, other studies have reported that vigorous types are relatively unaffected by sleep loss and require less sleep to feel refreshed (Di Milia and Folkard 2021; Folkard et al. 1979). We recommend that future studies seek to validate the behaviour of vigorous types against physiological indicators of sleep and alertness.

The results did not support the expectation that flexible types would also be associated with fewer injuries and better alertness. Flexible types are suggested to have a lower amplitude Process C, and Figure 3 shows that the amplitude of the alertness ratings for flexible types was smaller than the pattern for rigid types, but these differences were not significant. One possibility may be that our participants worked approximately 8-hour shifts compared to 12-hour shifts, where significant differences in alertness were previously reported (Di Milia et al. 2005). This difference in shift length may suggest that our participants were less fatigued across the shift. A second possibility is that our sample was dominated by females, whereas other studies suggesting alertness differences were dominated by males (Di Milia et al. 2005). However, we controlled for age and sex, and these findings suggest that the present results may be more robust. One study reported that vigour decreases with age and females, reported higher mean scores for vigour than males (Di Milia and Folkard 2021). We recommend more studies investigate the relationship between, age, gender, vigour and flexibility.

Overall, the findings that vigorous types had fewer injuries and greater alertness provide partial support for the proposition that vigorous and flexible types are better suited for night work (Folkard et al. 1979). The findings lead us to cautiously propose that vigorous types may be more tolerant of accommodating the demands of shift- and night work. However, we encourage future studies to replicate our findings and employ longitudinal designs in the hope these findings may generalise into other work settings.

The third contribution is that our results provide additional evidence for the measurement properties of the CTI. First, whereas other studies have established construct validity for the CTI (Di Milia et al. 2005), the finding that vigour moderates the link between shift work and injury provides for the first-time criterion-related validity. Second, we replicated the factor structure, and this finding adds to the evidence that the factor structure is sound and stable over an eight-year period (Pallesen et al. 2021). Moreover, we found the scales to have good reliability. Vigour and flexibility are theoretically presented as measuring different aspects of the circadian rhythm, and the fact these constructs were not correlated suggests they are independent constructs. The use of measurement scales that are reliable and valid is critical in mapping the relationships between variables of interest.

There are several approaches available for mitigating the detrimental impact of shift work. These include pharmacological interventions (e.g. coffee and medication), but the evidence appears weak and problematic (Liira et al. 2014), and there is preliminary evidence that light treatment facilitates a circadian shift (Lam and Chung 2021). Our findings suggest that vigour may be an important attribute of tolerance to shift work. It is appealing to suggest that vigour be considered a recruitment attribute, but this goal is premature given the absence of long-term longitudinal studies focused on individual differences and well-being during night shift. Even if the science was perfected, our anecdotal experience is that workers choose shift work for financial and other lifestyle benefits. Nonetheless, the CTI (Di Milia et al. 2005) could be used as a counselling tool to provide potential shift workers with information to self-assess their suitability for these working arrangements or to consider countermeasures to assist them with shift work.

The last decade has seen increased interest in measuring circadian rhythm amplitude. For example, the Morningness-Eveningness-Stability scale (MESS; Randler et al. 2016) includes a "distinctiveness" scale to assess amplitude considered to be the daily variation in mental and physiological arousal. Oginska et al. (2017) developed the Chronotype Questionnaire to measure "smaller" and larger' amplitudes. These self-report tools for measuring amplitude have the advantage of collecting large amounts of data in a non-invasive way compared to taking physiological assays. However, work has begun to establish genetic and other physiological markers that map onto circadian constructs will lead to further developments in measuring rhythm characteristics. For example, an association has been found between the phenotype PER2/3 and morningness (Degenfellner et al. 2021). Recently, Zareba et al. (2023) used neuroimaging to link rhythm amplitude (Oginska et al. 2017) with negative affect processing.

The findings need to be considered with respect to some limitations. We used a cross-sectional design, which prevents causal inferences from being made. Second, we used a convenience sample of workers which may create bias in the sample. On the other hand, the Australian and British samples contained similar proportions of day and shift workers, and the percentage of shift workers in the overall sample (55%) was consistent with estimates of shift work in the nursing profession (Querstret et al. 2020). The data were self-reported, which may question the validity of the number of injuries that were reported. It is tempting to recommend that future studies use objective injury data, but Galizzi et al. (2010) estimated that only 63% of serious injuries are reported in response to time pressure, concern about personal reputation and future career prospects. Self-report data are open to criticism of common method variance. While we cannot rule out this possibility, the results from Harmans single-factor test suggest this is unlikely to be the case. Recent evidence suggests that Harmans single-factor test is sufficiently robust to detect bias in survey-based research (Fuller et al. 2016). Finally, we do not have information on the participants experience with day or shift work to suggest whether this variable may have influenced our results. Establishing a link between aging and shift work is not straight forward because some samples may be affected by a "healthy shift worker" effect – the notion that workers that are unable to cope with shift work return to day work (Gommans et al. 2015). However, the Nurses' Health study tracked over 46 000 nurses aged about 48 years old working rotating night shift work over a 24-year period and only approximately 8% of this cohort achieved healthy aging defined as being over 70 years of age and free of eleven chronic diseases, memory and physical impairment, and sound mental health (Shi et al. 2022).

Conclusions

Shift work has long been associated with several physical and health-related impairments (Härmä et al. 2023; Sallinen and Kecklund 2010). Various models of shift work and health (Smith et al. 1999) suggest the importance of individual differences in adjusting to shift work and this study provides initial evidence for the benefits of vigorous types. Higher levels of vigour were associated with less injury on shift work and greater alertness across the day. These findings suggest that vigorous types may have a greater tolerance for shift work. Consistent with other studies we found the CTI (Di Milia et al. 2005) to have strong measurement properties.

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Author Contributions

LDM codesigned the study, collected the data, conducted the analyses, and drafted the manuscript. JBF codesigned the study, reviewed and contributed to the final manuscript. SF and RL reviewed and contributed to the final manuscript.

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Data Availability Statement

The data are available on request from the first author.

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