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Review Article

Identifying shift worker chronotype: implications for health

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Abstract: Shift workers are at risk for developing serious health issues due to short sleep. One cause of short sleep is circadian misalignment: sleep time is not synchronized with the body's natural circadian rhythms. Although circadian rhythms are strongly driven by the light/dark cycle, humans have individualized sleep time preferences (chronotypes) based on genetics, development, and external influences. Evening chronotype individuals fall asleep later than average and have a higher risk for developing various noncommunicable diseases. What is unclear is the association between chronotype, shift work, and risks for acquiring chronic conditions. This review is focused on shift worker chronotype and associations with obesity. Because of the paucity of research, other health issues connected with circadian misalignment were included, allowing for a total of 21 research studies. Evidence from this review supports chronotype and certain health issues are associated with shift work, even after adjusting for short sleep duration. In addition, there is evidence to support future research on how shift worker chronotype matched with shift timing impacts worker health. Through better understanding of this interface, occupational health providers can provide more comprehensive worker education on the risks associated with shift work and sleep disturbances.

Key words: Night shift, Circadian misalignment, Circadian rhythm, Sleep, Work schedule tolerance

Identifying Shift Worker Chronotype: Implications for Health

One-third of all workers and 44% of night shift workers in the United States report short sleep (≤6 h in a 24-h period)[1)]. Evidence supports short sleep contributes to a multitude of health issues: cardiovascular disease, ischemic stroke, obesity, type 2 diabetes, various types of cancer[2)], an increased overall mortality[3)], and occupational safety concerns due to a decrease in cognition[4)]. In addition, short sleep can lead to presenteeism, absenteeism, and a decrease in productivity, causing an estimated combined economic loss of $680 billion annually across Canada, Germany, Japan, the United Kingdom, and the United States[5)].

The misalignment of shift timing to sleep and disruption to the circadian system is the major cause of short sleep in shift workers[6)]. The circadian system is composed of multiple circadian rhythms, which send signals to the body for controlling physiological processes, including wakefulness, digestion, glucose management, inflammatory responses, and body temperature[7)]. Triggered by environmental light and melatonin production, normally cycled circadian rhythms signal a body to be awake during the day and asleep at night. Disruption to circadian rhythms, and subsequently, these biological functions can lead to disease development[6, 7)]. This circadian misalignment occurs in shift workers who are required to be alert at night and sleep during the day, opposing the normal circadian

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rhythms in humans. Sleeping during the day, when the circadian rhythms are signaling the body to be awake, can lead to poor quality and shortened sleep, preventing full recovery from a night's work[8].

Chronotype, Circadian Misalignment, and Health

Humans have natural tendencies toward specific sleep/wake times. Chronotype is defined as the individual variations of sleep/wake times and are largely influenced by environmental light, genetics, and human development stages[9]. Most individuals (60%) fall in the intermediate stage, but chronotype can swing from extreme early risers (morning chronotype) to late night owls (evening chronotype)[10]. Circadian misalignment can occur when evening chronotypes must wake up early for day shift work, and morning chronotypes work night shift. This disconnect in preferred sleep time and timing imposed by social/work obligations, also known as social jetlag, can lead to sleep debt and development of chronic health conditions[9, 11].

Evidence from the research of circadian misalignment and disease development supports evening chronotypes (ET) to be most at risk for poor health. ET workers prefer to stay up late, and sleep in late, causing a phase delay of their circadian system[12]. Independent of sleep duration, ET has been associated with increased resting heart rate, higher blood pressure, elevated stress hormones[13], sleep apnea, lower HDL levels, and higher BMI[14], and type 2 diabetes[15, 16]. Roenneberg *et al.*[11] conducted an epidemiological study (N=64,039) in central Europe on the impact of social jetlag on obesity. Social jetlag is defined as the difference between mid-sleep on workdays and mid-sleep on free days[9] and represents a potential variance between the body's sleep timing preference and the necessary sleep timing for going to work, school, etc. Roenneberg *et al.*[11] found increased social jetlag (largely found in ET) was associated with higher rates of obesity. In a study of a Finnish population (N=4,414), Basnet *et al.*[17] found ET to be associated with depression, cardiac insufficiency, gallstones, and COPD.

Additional research into circadian misalignment and associated disease risk has been conducted in shift workers. Evidence supports shift workers are more prone to metabolic disorders due to circadian misalignment, suggesting the cause is not from shortened sleep duration alone[18, 19]. It is proposed that misalignment is disruptive to circadian rhythms, which regulate various hormones for metabolic health[18]. This hormone disruption, specifically the hormones leptin and ghrelin, may lead to increased hunger and decreased satiety, driving a desire for higher caloric foods, and increasing risk for obesity[19]. Other evidence supports there is equivalent caloric intake between day and night shift workers, but the majority of caloric intake occurring during night shift, as well as the higher intake of sugar, may be negatively impacting the metabolic health in night shift workers[14, 19].

If circadian misalignment can lead to disease in shift workers, what efforts can protect workers? Reducing staff working night shift is helpful, but eradicating shift work in the fields of emergency response, healthcare, protective services, and other occupations is not an option. Research by Juda *et al.*[20] supports shift workers have improved sleep duration, sleep quality and decrease in social jetlag when the shift time correlates with the worker chronotype. Researchers matching chronotype to shift time with steel workers (N=114) found improved sleep duration, quality, and wellbeing[21]. The question remains whether identifying shift worker chronotype can predict disease development, thus providing workers and occupational health and safety professionals with a tool for determining risks and providing guidance to employees. The purpose of this paper is to review the literature regarding shift worker chronotype and association with obesity. Obesity was the chosen disease focus, as it is a risk factor for development of type 2 diabetes, cardiovascular disease, and certain cancers[22].

Review Methods

Using Polit and Beck's[23] framework for conducting a literature review, a five-year CINAHL, Scopus, and Pubmed search was conducted for articles published before August of 2017. Search words included chronotype, circadian, circadian rhythm, circadian misalignment, diurnal preference, morningness-eveningness, social jetlag, night shift, work schedule tolerance, shift work, and obesity. Ancestry and descendancy approaches also were used. From this search, 534 research articles were found. After duplicates were dismissed, articles were reviewed for relevance. Because only five articles had obesity as a dependent variable, the search was broadened to other sleep and health outcomes associated with shift worker chronotype. Sixteen additional articles were found: nine regarding various other health issues and seven regarding the sleep health of shift workers (Table 1).

Table 1. Integrative review results

Authors/yr	Study population, age, size, and location	Variables	Chronotype measurement tool	Statistical methods	Findings
Asaoka, Aritake, Komoda, Ozaki, Odagiri, Shimomitsu, & Inoue, 2013	-Nurses Fast forward rotating shifts -Mean age: 30.0 yr -N=1,202 -Tokyo, Japan	IV: Chronotype DV: SWD	Diurnal type scale	Multivariate logistic regression	-ET was positively associated with SWD.
De Souza & Hidalgo, 2015	-Full-time day workers -Mean age: 44.65 yr (male) 42.28 yr (female) -N=825 -Brazil	IV: Sleep midpoint IV: Sleep duration DV: Well-being	Munich chronotype questionnaire	Multiple hierarchical regression	-Women who had a later sleeping midpoint (ET) & shorter sleep duration were significantly associated with decreased well-being.
Dickerman, Markt, Koskenvuo, Hublin, Pukkala, Mucci, & Kaprio, 2016	-Twins engaged in shift work -Mean age: 40.0 yr -N=11,370 -Finland	IV: Chronotype IV: Sleep duration IV: Sleep quality DV: Prostate cancer	Questions pulled from the morningness-eveningness questionnaire	Cox proportional hazards regression	-ET dayshift workers had 1.3-fold higher risk of prostate cancer incidence, as compared to morning types. -Result non-significant when analyzed within twin pairs.
Furusawa, Okubo, Kuroda, Umekage, Nagashima, & Suwazono, 2015	-Male dayshift factory workers -Mean age: 44.8 yr -N=884 -Japan	IV: Chronotype DV: Depression, chronic fatigue	Morningness-eveningness questionnaire	Logistic regression	-Intermediate types had higher significant odds ratio of depression and chronic fatigue than MT. -ET scores were higher, but not significant.
Hansen & Lassen, 2012	-Female military employees -Age range: 37–75 yr -N=18,551 -Denmark	IV: Night shift Mediator: Chronotype DV: Breast cancer	Not defined	Multivariate logistic regression	-MT working night shift had 3.9-fold risk of breast cancer. -ET working night shift had 2.0-fold risk. -Intermediate types did not have an increased risk in breast cancer.
Haraszti, Purebl, Salavecz, Poole, Dockray, & Steptoe, 2014	-Women working at a University Dayshift -Age range: 21–65 yr -N=202 -Budapest, Hungary	IV: Chronotype DV: Depression DV: Self-perceived well being DV: Stress levels DV: Physical activity DV: Fruit and vegetable intake	Composite scale of morningness	Linear & logistic regression Hierarchical regression analysis	-MT assoc w/ lower depressive symptoms, greater well-being scores, >frequency physical activity & fruit/veggie intake. -ET associated with higher stress levels.
Haus, Reinberg, Mauvieux, Le Floc'h, Sackett-Lundeen, Touitou, 2016	-Male factory shift workers Rotating shifts -Age range: 20–67 yr -N=67 -France	IV: Chronotype IV: Age DV: Obesity	Body temperature fluctuations	Multiple regression	-Circadian desynchronization and age together are associated with elevated BMI. -Length of shift work and rotation speed were not significant factors.

Table 1 Continued.

Authors/yr	Study population, age, size, and location	Variables	Chronotype measurement tool	Statistical methods	Findings
Juda, Vetter, & Roenneberg, 2013	-Shift workers Rotating 3 shifts, fast & slow rotations -Mean age: 38.8 yr -N=238 -Germany	IV: Chronotype DV: Social jetlag DV: Sleep duration DV: Sleep quality	Munich chronotype questionnaire	Mixed-model ANOVA	-When working day shift, ET had higher social jetlag, shorter sleep duration, & lower quality sleep than MT. -MT experienced shorter sleep duration & lower sleep quality when working night shift.
Lee, Chen, Tseng, Lee, & Huang, 2015	-Nurses in medical centers rotating shifts on either a monthly or weekly basis - Age range: 18.8% <25 yr 67.1% 25–39 yr 14.1% ≥40 yr -N=398 -Taiwan	IV: Chronotype IV: Emotional disturbance IV: Insomnia vulnerability DV: Sleep quality	Smith Morningness-eveningness questionnaire	Linear regression Causal steps approach Multiple mediator model	-Chronotype did not solely impact sleep quality scores. -MT working night shift had shorter sleep duration when shift timing was added as a moderator to the model. -ET did have decreased sleep quality when emotional disturbance was added to the model as a mediator.
Martin, Laberge, Sasseville, Berube, Alain, Houle, & Hebert, 2015	-Police officers Counter-clockwise fast rotating shift schedule -Mean age: 28.9 yr -N=39 -Quebec City	IV: Chronotype IV: Shift timing DV: sleep DV: activity light exposure	Morningness-eveningness questionnaire	Mixed models	-ET experience lower sleep quality & duration regardless of shift timing. -Total sleep time did not differ between night & day-shift (after compensation w/ naps).
Mota, Waterhouse, De-Souza, Rossato, Silve, Araujo, Tufik, de Mello, & Crispim, 2016	-Medical residents -Mean age: 29.2 yr -N=72 -Brazil	IV: Chronotype DV: Food intake DV: Physical activity DV: Sleep patterns	Morningness-eveningness questionnaire	Linear regression Multiple linear regression models	-ET chronotype associated with higher caloric, sweet and vegetable intake and lower fat & oil intake. Also associated with lower activity levels. -Chronotype was not associated with obesity.
Ramin, Devore, Pierre-Paul, Duffy, Hankinson, & Schernhammer, 2013	-Nurses -Median age range among various chronotypes: 52.7–53.2 yr -N=72,517 -United States	IV: Chronotype Moderator: shift rotation DV: Breast Cancer	Question from the morningness-eveningness questionnaire	Multivariable-adjusted logistic regression models	-Intermediate chronotypes had a 27% increased risk of breast cancer, compared to definite MT. -History of rotating shifts, which included night shift hours, did not impact the association.
Reinke, Ozbay, Dieperink, & Tullenken, 2015	-ICU nurses in a University Medical Center Rotating day/night 8hr shifts -Mean age: ET: 43.85 yr MT: 40.70 yr -N=96 -Netherlands	IV: Chronotype DV: Sleep patterns DV: Reaction time DV: Cognitive ability (quick problem solving)	Munich chronotype questionnaire	t-test & Mann-Whitney U	-MT napped more frequently before night shift. -No noted differences in response time or cognition, regardless of shift timing.

Table 1 Continued.

Authors/yr	Study population, age, size, and location	Variables	Chronotype measurement tool	Statistical methods	Findings
Togo, Yoshizake, & Komatsu, 2017	-Nurses working in institutions Day and rotating shifts -Mean age Day shift: 41.5 yr Rotating shift: 40.2 yr -N=2,669 -Kanagawa Prefecture, Japan	IV: Chronotype IV: Sleep duration IV: Rotating shift DV: Depressive symptoms	Morningness-eveningness questionnaire	Multivariate linear regression w/ covariate model adjusting for covariates such as socio-demographic, drinking, and smoking	-Lower nurse chronotype scores (those indicating ET) were significantly associated with higher depressive symptom scores. -Shorter sleep duration was also associated with higher depressive symptom scores. -There was no interaction effect when nurses worked rotating shifts.
Van de Ven, Van der Klink, Vetter, Roennenberg, Gordijn, Koolhaas, de Looze, Brouwer, & Bultmann, 2016	-Industrial shift workers Rotating shifts -Mean age: 44.36 yr -N=261 -Netherlands	IV: Chronotype IV: Age DV: Sleep duration DV: Sleep quality DV: Recovery	Munich chronotype questionnaire	Logistic regression	-ET was associated with shorter sleep duration, decreased sleep quality, longer need for recovery when working days. -Sleep duration improved when ET worked nights. -Age was not a statistically significant variable.
Vetter, Devore, Ramin, Speizer, Willett, & Schernhammer, 2015	-Registered nurses working Rotating shifts -Mean age: 54.2 yr -N=64,615 -United States	IV: Chronotype DV: obesity DV: T2DM Mediating variable: shift work	Morningness-eveningness questionnaire	Multivariable logistic regression	-Compared MT to ET, physical activity is lower, BMI is higher, sleep duration is lower. -MT have lower T2DM compared to intermediates, which increased with more years of shift rotation. -ET working days had higher association with T2DM.
Wong, Hasler, Kamarck, Muldoon, & Manuck, 2015	-Shift workers, working day shift -Mean age: 42.7 yr -N=447 -United States	IV: Chronotype DV: Cardiovascular disease risk factors	Composite scale of morningness	Multiple regression analyses	-ET experiencing higher SJL were positively associated with triglycerides, fasting insulin, insulin resistance, waist circumference, & BMI. -ET with higher SJL were negatively associated w/ HDL levels.
Wyse, Morales, Graham, Fan, Ward, Curtis, Mackay, Smith, Bailey, Biello, Gill, & Pell, 2017	-Shift workers from various occupations -Age range: 35–74 yr -N=277,168 -United Kingdom	IV: Shiftwork Covariate: Chronotype DV: Obesity DV: Diabetes DV: Sleep disturbance DV: Depression	Self-report of MT or ET	Logistic regression	-No association between shift work, chronotype & BMI. -MT reported higher levels of short sleep duration. -ET reported more insomnia & daytime sleepiness.
Yadav, Rani, Singh, 2016	-Police officers -N=85 -Mean age: 26.64 yr -India	IV: Chronotype DV: Sleep DV: Blood pressure DV: Heart rate	Morningness-eveningness questionnaire	Repeated measures 2-way ANOVA	-Matching chronotype and shift resulted in a decrease in sleep fragmentation, improved sleep quality, lower HR.

Table 1 Continued.

Authors/yr	Study population, age, size, and location	Variables	Chronotype measurement tool	Statistical methods	Findings
Yazdi, Sdeghniiat-Haghighi, Javadi, & Rikhtegar, 2014	-Female nurses working shift work in university hospitals - Mean age: 31.3 yr -N=160 -Iran	IV: Chronotype DV: Sleep quality DV: Insomnia	Morningness-eveningness questionnaire	Logistic regression	-ET was associated with decreased sleep quality.
Zhang, Duffy, de Castillero, & Wang, 2017	-RNs & LPNs in a hospital setting 8hr & 12hr non-rotating shifts (day-shift, evening, and night shift) -Mean age: 43.2 yr -N=397 -Northeast United States	IV: Chronotype IV: Sleep characteristics DV: Work related MSD	A modified question from the morningness-eveningness questionnaire	Poisson regression modeling	-ET associated with higher MSD incidence. -ET has an increased risk of MSDs.

Results

Shift work, chronotype, and obesity

Results are mixed among studies about shift work, chronotype, and obesity. Researchers for three of the five articles found a positive association with ET shift workers and obesity. Haus *et al.*[24] used body temperature to measure chronotype and circadian misalignment. The study was a secondary analysis of data from male French oil refinery shift workers. Using multiple regression analysis, misalignment only accounted for an increase in obesity when worker age was included in the model. Length of shift work exposure and speed of shift rotation were not significant factors in obesity. Vetter *et al.*[25] analyzed data collected during 2005–2011 from the Nurses' Health Study 2, which included 64,615 female nurses, who worked rotating shifts. Using a question from the Morningness-Eveningness Questionnaire[26], the researchers determined 35% of respondents identified as morning chronotypes (MT), 54% as intermediate chronotypes, and 11% as ET. Their statistical analysis supported the stronger the nurses' ET score, the less they engaged in physical activity and the higher their BMIs. Wong *et al.*[27] investigated whether chronotype is associated with obesity and other risk factors for cardiovascular disease, independently of poor sleep duration and quality. Chronotype was measured among day shift workers using the Composite Morningness Scale[28]. Sleep disturbances were measured via actigraphy data. Multiple regression analysis substantiated ET was associated with higher BMI and waist circumference, even after controlling for sleep disturbances.

In contrast, researchers for two studies did not support chronotype association with obesity. Mota *et al.*[29] recruited Brazilian medical residents (N=72) who had been practicing for a minimum of seven months, working approximately 60 h per wk, with some shifts being 12 h. Chronotype was measured with the Morningness-Eveningness Questionnaire[26], in addition to sleep quality, duration, physical activity, food intake, and anthropometric variables. After accounting for sleep characteristics in the model, chronotype was not associated with obesity. Accessing a large database, Wyse *et al.*[30] analyzed results from 277,168 participants, with 17% being shift workers. Chronotype was determined by self-report of morning or evening preference. Although results maintain an association between shift work and obesity, there was not a relationship between chronotype and obesity. Interestingly, the researchers concluded night shift workers were more likely to identify as ET.

Several researchers examined health behaviors tied to obesity: physical activity and caloric intake[22]. Haraszti *et al.*[31] collected data from 202 full-time working women in Hungary. Using the Composite Morningness Scale[28] to measure chronotype, researchers used the data to examine its association to various health behaviors, such as diet, exercise, smoking, and alcohol intake. The only significant finding was MT workers were associated with increased exercise frequency. In Mota *et al*'s[29] study of 72 medical residents, ET was associated with higher daily caloric intake and higher protein, cholesterol, sugar, and vegetable intake. ET was associated with lower oil and fats intake. Significant results also linked lower levels of physical activity with ET, and higher levels with MT, similar to the findings by Vetter *et al*[25].

Shift work, chronotype, and various health issues

Metabolic health

In their studies, Vetter *et al.*[25] and Wong *et al.*[27] did not only examine chronotype association with obesity, but also metabolic health conditions. Vetter *et al.*[25] hypothesized mismatched chronotype with work time would increase risk for type 2 diabetes. Data analysis supported MT workers had a decrease risk for type 2 diabetes, when working day shift. Working extended periods of night shift increased risk for MT workers. In ET workers, those who had never worked night shift had a 1.5-fold increased risk of developing type 2 diabetes, whereas in comparison, ET workers who had worked night shift had a lower risk. Wong *et al.*[27] found ET to be associated with higher triglycerides and higher insulin resistance.

Cancer

Dickerman *et al.*[32] conducted a prospective study of 11,370 Finnish male twins, to examine the association of mid-life sleep to prostate cancer diagnoses. Respondents were shift workers, including some with rotating shifts. Sleep characteristics, such as duration and quality were measured, along with chronotype via self-report. ET workers had a higher risk of prostate cancer, when compared to MT workers, and particularly when chronotype did not match work times (thus increasing social jetlag). Additional analysis between discordant twin pairs did not show a significant association between chronotype and prostate cancer. Of note, in the overall study, sleep duration and sleep quality did not influence prostate cancer risk.

Hansen and Lassen[33] explored relationships between night shift, sun exposure, chronotype and breast cancer in a study population of 18,551 Danish female military personnel. Chronotype was measured via self-report in answering preference to morning, evening, or neither. Results support MT workers on night shift had a 3.9-fold risk of developing breast cancer, in comparison to ET workers at 2.0. In comparison, the group not indicating a chronotype preference did not show an increase in risk. Like Dickerman *et al.*[32], this study supports the mismatch of chronotype with timing of shifts to have a greater influence on cancer development than shift work alone.

An additional study reviewed the relationship between chronotype and breast cancer among nurses (N=72,517) in the United States[34]. Participants in the Nurse's Health Study II self-reported chronotype via a question from the Morningness-Eveningness Questionnaire[26]. Study participants could choose from five possible answers on the continuum of "definitely a morning type" to "definitely an evening type." Researchers collected evidence of frequency of night shifts worked during the ongoing surveys collected from 1989 to 2009. Participants were asked about breast cancer diagnosis status in 1989 and 1991 to 2009. Using multivariable adjusted logistic regression models, the researchers controlled for various confounding factors, such as age, smoking status, and physical activity. Additionally, researchers stratified rotating night shift work history by incidence of this exposure to examine how much impact rotating night shift work had on the chronotype and breast cancer interaction. Researchers discovered nurses identifying as being neither MT or ET had a 27% increase risk of breast cancer (OR=1.27, 95% CI 0.87–1.12). Rotating night shift work had no influence on the chronotype and breast cancer interaction.

Work-related musculoskeletal disorders

Zhang *et al.*[35] considered the association of chronotype, sleep characteristics, and work-related musculoskeletal disorders. The study population of American nurses, working in a hospital setting, self-reported chronotype preference via the Morningness-Eveningness Questionnaire[26]. Multivariate analysis supported ET was significantly related to increased risk of work-related musculoskeletal disorders, even after adjusting the model for shift timing. In addition, obesity was associated with work-related musculoskeletal disorders. Sleep duration and/or disturbances were not significantly related to work-related musculoskeletal disorders.

Mental health

Researchers of five articles discuss the association of chronotype on characteristics and conditions related to

mental health. Asaoka *et al.*[36] determined chronotype (via the Diurnal Type Scale[37]) of Japanese nurses working fast-forward rotation schedules (a rotation through all shifts within one week). Researchers were looking for association with chronotype and diagnosis of shift work disorder which is characterized by excessive sleepiness or insomnia from circadian system disruption[38]. Those identified as ET were significantly related with shift work disorder, which in turn, was also associated with decreased quality of life and increased symptoms of depression. Haraszti *et al.*[31] also investigated the relationship between chronotype and depression in Hungarian women working dayshift. MT was significantly associated with less depression, greater well-being scores, and lower stress levels. Furusawa *et al.*[39] examined chronotype and depression, but with a Japanese male study population of 884 dayshift factory workers. Intermediate chronotype workers had higher odds ratios of depression and chronic fatigue, than their MT worker counterparts. ET workers had higher incidences of depression and chronic fatigue than intermediate chronotype workers, but did not reach statistical significance. Researchers suspect this is due to low power from the small number of workers identified as ET. In Togo *et al.*[40] study of day and rotating shift nurses in Japan (N=3,032), the hypothesis was nurses self identified as ET would have more symptoms of depression. Additionally, they hypothesized shorter sleep duration would negatively correlate with depressive symptoms and that shift rotation would not. Using multivariate linear regression, the researchers found support for their hypotheses, finding a mismatch of ET nurse chronotype with dayshift hours increasing symptoms of depression.

de Souza and Hidalgo[41] studied the correlation of chronotype in Brazillian workers with psychological well-being. Chronotype was measured using the Munich Chronotype Questionnaire[42]. Workers were dichotomously grouped by gender, revealing women to have more ET characteristics, which was significantly associated with reports of depressive symptoms. One explanation for the difference between genders is the male population was largely recruited from an agricultural community, thus providing a large dose of exposure to a circadian timing cue, the sun.

Shift work, chronotype, and sleep characteristics

Martin *et al.*[43] identified chronotypes in 39 Quebec City police officers and studied the relationship between chronotypes and sleep. Using the Morningness-Eveningness Questionnaire[26] for measuring chronotype, and actigraph for determining sleep characteristics, data analysis supported ET workers had decreased sleep duration and quality when compared to intermediate types. This persisted after model adjustment for shift timing. Interestingly, the total sleep duration was equal among all chronotypes, when naps were included. Still, the total sleep time for all chronotypes averaged at 6 h, less than the 7–9 h of sleep in a 24-h period recommended for healthy adults[44]. Similarly, Yazdi *et al.*[45] found nurses self-reporting as ET (via the Morningness-Eveningness Questionnaire[26] experienced decreased sleep quality. The nurses were in three different eight-hour shift groups of fixed night shift, rapid rotation shifts, and slow rotation shifts. The researchers used logistic regression to determine chronotype influence on sleep quality and insomnia. Although ET did have higher insomnia scores, the results were not statistically significant. Shift timing and shift rotation were not significantly associated with sleep quality and insomnia.

Reinke *et al.*[46] found social jetlag was higher for workers of both chronotypes. These researchers examined the sleep characteristics of 96 intensive care unit nurses in the Netherlands. Similar to Martin *et al.*[43], total sleep duration was not impacted by chronotype or shift, when adding nap time into total duration. There was a noted difference in nap timing among the chronotypes, with more MT napping before working night shift.

In contrast, researchers of three studies support improved sleep characteristics when matching ET with night shift. Juda *et al.*[20] supported this hypothesis when studying 238 German shift workers, working various levels of rotating shifts. ET workers have longer sleep duration when their shift matched their chronotype. Employees identified as ET experienced shortened sleep and poor sleep quality when working day shift. Likewise, MT workers experienced shortened sleep and poor sleep quality when working night shift. van de Ven *et al.*[47] found similar results among rotating shift workers in the industrial sector in the Netherlands. Workers who had a chronotype that did not align with the shift worked had shorter sleep duration, quality, and longer time for recovery. In addition, older workers reported decreased sleep duration and quality, regardless of shift timing. In studying police officers in India, Yadav *et al.*[48] found participants had decreased sleep duration and quality when working shifts misaligned with their identified chronotype.

Lee *et al.*[49] also found a mismatch of chronotype with shift timing impacted sleep duration. In a study of nurses (N=398), MT working night shift had a shorter sleep duration than ET working night shift. The main focus of this

study was to investigate the relationship of chronotype with emotional disturbance and insomnia vulnerability on sleep quality. Chronotype, alone, did not influence sleep quality. Using the causal steps approach and a multiple mediator model, the researchers did find evidence of the indirect effect of ET on sleep quality when emotional disturbance is added as a mediator.

Discussion

Chronotype and obesity

Because obesity and short/disturbed sleep are growing health problems across the globe, and both are associated with multiple chronic health conditions, investigating an association among shift workers is critical[5, 50]. By associating chronotype and circadian misalignment, workers could make more informed decisions about their potential personal health risks with working various shifts. Therefore, the initial purpose of this review was to examine shift worker chronotype with obesity. This focus resulted in only five studies, multiple methods for studying this phenomenon, and mixed results. Only some studies included workers on rotating shifts, which could impact results due to the high probability of circadian misalignment with rotations[51]. Other factors which could influence results were the varying occupations and age of study participants across the five studies. Each occupation has different environments, workloads, and physical expectations each potentially contributing to or preventing obesity in the worker population[22]. Regarding age, although all the study subjects were adult workers, it was not always clear how many outliers existed. Considering how chronotype can change with development and age, these outliers could result in more MT or ET in the studies, potentially not matching the true representation of chronotype in the population.

Another explanation for mixed results could be the multiple risk factors for obesity[22]. In three studies, researchers did link shift worker chronotype to obesity-contributing behaviors, such as decreased physical activity and increased caloric intake[25, 29, 31]. Further research investigating chronotype, shift work, and caloric intake may be helpful, as the timing of dietary intake and the ingestion of high fat foods can disrupt circadian rhythms, leading to obesity[18]. Another possible contributing factor is depression. Luppino *et al.*,[52] in their meta-analysis, found obesity and depression have a mutual relationship. In this review, ET and circadian mismatch was associated with depression[31, 36, 41]. Considering the relationship between shift worker chronotype and depression, perhaps investigating the possible mediating impact of chronotype when shift workers suffer from depression and obesity is a literature gap worth scrutinizing.

Finally, the chronotype measurements were inconsistent among the studies, with one study not identifying a reliable and valid instrument for measuring chronotype[24]. This is of concern because not all tools measure chronotype in the same way and may have different biases related to self-report and recall. Some chronotype instruments are lacking psychometrics completed with the shift worker population[10]. Wording on instruments aimed at the general population (i.e.: "what time do you wake up in the morning?") may cause confusion for night shift workers who are getting ready for sleep in the morning, potentially resulting in biased responses.

Chronotype, health, and sleep

Overall, the studies in this review support a potential association in shift worker chronotype and health. Instead of linking a specific chronotype with a specific disease development, researchers from five studies ascertain the mismatch of chronotype to shift timing as the most indicative of predicting disease[25, 27, 32, 33, 40]. Two of the studies were prospective cohort designs, studying prostate cancer (31 yr) and metabolic disorders (six year study)[25, 32]. A third study used a nested case control design to examine breast cancer[33]. These study designs can provide strong evidence supporting the risks of occupational exposures (such as chronotype misalignment with shift timing) on developing disease (particularly latent processes such as cancers)[53]. Additionally, several of the researchers adjusted for short sleep duration and found results remained significant between chronotype misalignment and the dependent variable of interests (diabetes, higher trigylcerides, lower HDL, and prostate cancer)[25, 27, 32]. Interestingly, in one study an association was not found between chronotype and disease (obesity), but researchers hypothesize it was due to a majority of the night shift workers had ET chronotype, and therefore, worked a shift time matched to their circadian system[30].

Further support in the relationship of matching chronotype to shift timing was found in the studies focused on sleep characteristics[20, 45, 47, 48, 49]. The research strongly supported chronotype misaligned with shift timing was associated with decreased sleep duration and quality[20, 48]. In fact, Juda *et al*'s[20] data analysis supported ET workers matched with evening shift reported longer sleep duration than MT workers on the same shift. Lee *et al.*[49] only

found a significant association between chronotype and sleep quality when the statistical model included emotional disturbance as a mediator. These conclusions suggest a specific chronotype or shift and its association with disease and sleep disturbances may be more complicated, involving other personal characteristics. Further research regarding circadian rhythms and chronotype misaligned with shift timing as an antecedent for disease and sleep disturbances is necessary.

Limitations

There were several potential limitations of this review. A limited number of studies on any one specific disease outcome prevented any conclusions relating chronotype to those diseases. Because the review was investigating a finite study period of five years, some studies may have been published outside of the search dates. Additionally, studies not published in English were excluded. Because tools, study design, and outcome variables in the included studies were so wide ranging, it was not feasible to conduct a meta-analysis on these studies.

Conclusion

The importance of sleep to health has been equated to diet and exercise[2]. The complexity of this interplay is still being investigated. Epidemiological studies support short sleep duration has negative health implications[2], but additional research is indicating sleep timing also may play a role[9, 11]. It is clear further investigation is needed to better ascertain the intricate interactions of shift work, sleep timing, and individual chronotype on shift worker health. At the very least, chronotype needs to be considered in studies of shift work, sleep, and disease outcomes. Because chronotype influences an individual's sleep timing onset and awakening, it may result in an individual variation leading to disease susceptibility for a worker.

How individual circadian rhythms intersect with the demands of work timing need to be considered. By improving understanding, workers can make more informed decisions about shift work and how it may impact their health. Employers can feel increased confidence their employees are alert and fit for duty, regardless of shift timing.

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