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PART A: Effects of aging on tolerance and recovery from shift work: A narrative review

PART B: Effects of aging on tolerance and recovery from shift work: A systematic review

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PART B: 5,281
PART A: Effects of aging on tolerance and recovery from shift work: A narrative review

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Aging

Nowadays, there is an increasing interest in research about aging by different authors and perspectives, including natural science, biological science, medicine, economics, law, and the social and behavioural sciences. This particular attention may be due to the rise in the mean age of the population, the increase in life expectancy, and what changes these situations could bring for the future. Currently, according to the United Nations (2009), the world’s human population is about seven billion, and it is projected to surpass nine billion people by 2050. The additional two billion people will come from developing countries, while the population of the more developed regions is projected to change minimally, and even decline. The population of less developed regions is young, around 50 percent of their habitats are 24 years or younger, whereas in more industrialized countries this number only reaches approximately 30 percent, and is steadily decreasing. Young people are projected to decrease from 163 million to 134 million by 2050 because of lower birth rates. Globally, it is expected that fertility declines from 2.56 children per woman in 2005-2010 to 2.02 children per woman by 2045-2050. On the contrary, the population aged 60 and over is the fastest growing. In more developed countries the growth rate is two percent annually, and it is predicted to increase by more than 50 percent in the next decades, increasing from 264 million in 2009 to 416 million by 2050. Similarly, in less developed countries, the growth rate of the population is three percent annually, and it is projected to increase from 473 million in 2009 to 1.6 billion by 2050. This means that globally, people aged 60 and over are going to triple in the next few decades. In more developed regions, people aged 60 and over represent 21 percent of the population, and this figure is expected to increase to 33 percent by 2050. The median age of the world’s population is going to increase from 29 in 2009 to 38 in 2050, while in Europe (Oldest population) the median population age is expected to increase from 40 in 2009 to 47 by 2050.

Another significant contributing factor to population aging is increased longevity. Because of technological advances in medicine, better education, living standards, and working conditions, the global life expectancy at birth rose from 66.4 years old to 71.4 between 2000 and 2015 (WHO, 2015), and is predicted to grow to 76 by 2045-2050. While in developed regions, this figure increases from 77 in 2005-2010 to 83 in 2045-2050 (United Nations, 2009).
All these changes in population distribution affect the workforce in organisations as well. In the United States, the labour force aged 55 and above increased from 14.3 percent to 20.9 percent between 2002 and 2012, and it is expected to continue rising to 25.6 percent by 2022 (Toossi, 2013). While in the European Union, it is projected that by 2030, workers aged between 55 and 64 will represent 30% or more of the total workforce (European Agency for Safety and Health at Work, 2016). This change in the population structure presents new issues and opportunities for employers and workers. In several countries, the retirement age is increasing because of the higher life expectancy of workers, sustainability of pensions, and the need to provide enough manpower to industry in the near future. For example, the time table of the United Kingdom to increase the state pension age from 65 years old to 66 is between 2018 and 2020, to 67 is between 2026 and 2028, and to 68 years old between 2037 and 2039 (Department for Work & Pensions, 2017).

However, across Europe, numerous employees have decided to leave the labour market before reaching the official pensionable age, and some of the suggested factors contributing to this decision are: poor physical health, age discrimination, outdated skills, and lack of appreciation. From a biological and psychological point of view, aging means a progressive deterioration of various internal systems. Functions like oxygen consumption, visual accommodation, psychomotor reactions, and mental and social rigidity start to slowly deteriorate over time and become less efficient (Costa & Di Milia, 2008), but this does not mean that older workers are not fit to work.

In terms of age discrimination, research has shown that companies and supervisors hold negative stereotypes regarding older workers, provide them with less development or training, and treat them generally less fairly compared to young or middle-aged workers (de Lange et al., 2010). Some of the common stereotypes related to older workers are: poorer cognitive functioning, lower performance, more resistance to training and change, and more sickness absence. However, there is no real evidence of these suggestions in the working population (Bertolino, M. Truxillo, & Fraccaroli, 2013; Johnson, 2015; Ng & Feldman, 2008, 2010).

Due to this, and other circumstances, the employment rate of people aged 55-64 in the European Union is only 55.2 percent, which means that only half of the population in that age range have work. This figure is significantly lower compared to the 78.7 percent employment rate of people aged 25-54 years old (OECD, 2017). To solve this
issue, governments and companies will have to properly manage aging in the workforce by creating policies to secure employment, performance, well-being and health to older workers (Bourn, 2007; Cloostermans, Bekkers, Uiters, & Proper, 2014; Costa & Di Milia, 2008).

**Shift work**

The European Union, through the European Work Time Directive, defines shift work as “any method of organising work in shifts whereby workers succeed each other at the same work stations according to a certain pattern, including a rotating pattern, and which may be continuous or discontinuous, entailing the need for workers to work at different time over a given period of days or weeks” (European Commission, 2003, p. 2). Shift work usually means working during hours in the early morning, late afternoon, at night or during weekends; and the rest days do not always match with weekends. This type of work schedule has become particularly popular in the health, transport and communication, and manufacturing industries due to the need for continuous work, competitiveness, and high standards and requirements from customers. In the United Kingdom, 14 percent of employees work in a shift work system, of which 14.8 percent are males, and 13 percent are females. The most prevalent age group working in this pattern of work are those aged 16-24, of which 20.6 percent are males and 22.1 percent are females (Office of National Statistics, 2011). Similarly, The figures of employees working in a shift work system in the United States and the European Union are 15 percent and 17 percent respectively (Bureau of Labor Statistics, 2005; Parent-Thirion et al., 2012).

Shift work, as an informal work schedule, had been used long before the invention of sustainable sources of artificial light. Since the beginning of modern medicine, nursing is one example of a profession that has required work to be done in shifts. However, it was not until the invention of the electric light bulb, and the opening of the first power plant in 1882, that a steady and reliable source of power during the day and night was made possible, enabling a 24 hour formal shift work system (Gordon, Cleary, Parker, & Czeisler, 1986). Artificial light is considered one of the reasons for the dysregulation of the circadian system, and the problems associated with it.
Shift work and health problems

The impact of shift work on health started to grow relevance following the definition of shift work maladaptation syndrome, in which sleep disorders, gastrointestinal difficulties and increased risk of cardiovascular disease were the main symptoms related to this condition (Moore-Ede & Richardson, 1985). Nowadays, shift work maladaptation syndrome is called shift work disorder, and it is defined as dysregulation of the circadian cycle, resulting in insomnia, sleepiness and fatigue (Åkerstedt & Wright, 2009). Nevertheless, research also suggests there are a variety of other problems associated with shift work, like cardiovascular disease, cancer, gastrointestinal issues and mental health problems.

Sleep problems

The study of sleep and shift work has been a common topic among researchers, whose primary objective has been to identify and compare the quantity and quality of sleep between shift workers and day workers, using different types of measures like insomnia, sleep disruption and sleepiness (Åkerstedt & Wright, 2009). A wide range of primary and review studies have established a solid association between shift work and sleep difficulties (Åkerstedt & Wright, 2009; Chan, 2009; Costa, 2010; Winwood, Winefield, & Lushington, 2006). Sleep problems are most frequently complained about by shift workers, and it is estimated that about 10% of shift and night workers suffer from shift work sleep disorder (Drake, Roehrs, Richardson, Walsh, & Roth, 2004).

The measurement of the quantity and quality of sleep is usually assessed by different types of instruments and questionnaires, such as polysomnography, actigraphy, the Bergen Insomnia Scale, Epworth Sleepiness Scale, and Pittsburgh Sleep Quality Index among others.

It is suggested that the link between shift work and sleep problems is due to the dysregulation of the circadian rhythms resulting from the abnormal sleep-wake patterns. Shift and night work requires employees to live and work in a different pattern compared to day workers, which affects the internal biological synchronicity. Circadian rhythms are physiologic and behavioural cycles, with a recurring periodicity of about 24 hours, which are driven by the biological pacemaker, the suprachiasmatic nucleus (SCN) located in the hypothalamus, and synchronised by environmental cues or stimuli (e.g. the light/dark cycle) called zeitgebers (Costa, 2010; Zee, Attarian, & Videnovic, 2013). These rhythms
control a variety of internal biological processes, like the sleep-wake cycle, eating, hormone secretion, body temperature, glucose secretion and homeostasis. The misalignment of the circadian rhythms and the sleep pattern of shift and night work can reduce sleep by between two and four hours, which can be higher depending on environmental conditions like noise and light, or social responsibilities, such as family (Costa, 2010). Many, if not all, of the negative issues of shift and night work, are linked to the dysregulation of the circadian system and sleep patterns.

Cardiovascular disease

The association of cardiovascular disease and shift work is one of the most researched topics in this field, and it is widely suggested that working on a shift work system increases the rate of having cardiovascular problems (Puttonen et al., 2009). Additionally, the risk of suffering from cardiovascular disease increases for shift workers when combined with other factors well-known for their impact on the cardiovascular system like obesity, high caffeine intake and smoking. There are several hypotheses for the causal mechanisms behind the association between shift work and cardiovascular disease; one of them proposes that sleep loss affects the movement of the circadian rhythms, which in turn, produces major metabolic changes in the body (Frost, Kolstad, & Bonde, 2009). Frost also suggested that the impact of cardiovascular disease and shift work can be due to stressful work environments, or to lifestyle factors (e.g. type of food eaten or physical activities). However, recent studies have claimed that there is limited evidence to suggest a causal effect (Frost et al., 2009), and other studies have shown no significant relationship between shift work and cardiovascular disease (Hublin et al., 2010).

Gastrointestinal disturbances

After sleeping problems, gastrointestinal troubles are the most common complaint by shift workers. Some of the symptoms related to gastrointestinal disturbances and shift work include gastritis, peptic ulcers, colitis, appetite disturbance constipation and abdominal pain (Knutsson & Bøggild, 2010). Evidence has suggested that the circadian desynchrony of the gastric function (e.g. gastric bile and pancreatic secretions, rate of absorptions of nutrients, enzyme activity, intestinal motility, and hunger and satiety hormones) could be the link between gastrointestinal disturbances and shift work (Costa, 1997). Nevertheless, recent research cannot confirm the association between shift work
and gastrointestinal complaints, peptic ulcers or gastritis (van Mark, Spallek, Groneberg, Kessel, & Weiler, 2010).

**Metabolic disorders**

Several studies have reported higher rates of metabolic syndromes such as obesity, overweight, increased triglycerides and higher total cholesterol blood levels in shift workers compared to day workers (De Bacquer et al., 2009). The relevance of these syndromes is due to their association with other types of health issues, like diabetes and cardiovascular diseases (Eckel, Grundy, & Zimmet, 2005).

It is suggested that numerous variables are responsible for the link between shift work and metabolic disorders like sleep and gastrointestinal problems, circadian system dysregulation, and changes in lifestyle (e.g. lack of exercise, quality and timing of meals, and poor diet) (Costa, 2010).

**Cancer**

In 2007, the International Agency for Research on Cancer reported that shift work that involves circadian disruption is “probably carcinogenic to humans” (International Agency for Research on Cancer, 2007). Epidemiological studies, focused on nurses and flight attendants, showed an increased risk of breast cancer compared to a woman who does not work at night. A recent study also has suggested an association between shift work and prostate cancer (Flynn-Evans, Mucci, Stevens, & Lockley, 2013). Other types of cancer also have been reported, endometrial and colorectal, but with less evidence to support the link (Schernhammer et al., 2003; Viswanathan & Schernhammer, 2009).

It is proposed that these associations are due to the disruption of the circadian system, which is caused by constant light at night or chronic jet lag, suppressing melatonin production and dysregulating genes and hormones related to tumour growth (International Agency for Research on Cancer, 2007). However, there are some studies which did not find a significant relationship between prostate or breast cancer (Pronk et al., 2010; Schwartzbaum, Ahlbom, & Feychting, 2007). It has been suggested that these discrepancies are related to methodological weaknesses like difficulties to control co-founders, and the poor definition (in terms of classification of workers) of shift work (Stevens et al., 2011).
Pregnancy Issues

According to some studies, there is a higher incidence of miscarriage and impaired fetal development in women shift workers compared to day workers (Nurminen, 1998). Mcdonald et al. (1988) showed that shift work has the second highest rate (after lifting heavy loads) of miscarriage compared to other physical factors at work. Additionally, it has been found that low fertility and higher abortion rates in shift work women are related to the adversities and complications in reconciling shift work schedules and family commitments (Costa, 2010).

Mental health

There are an increasing number of studies that have suggested that sleep deficit, in combination with higher work demands, and more difficult reconciliation of work and family responsibilities due to shift work, may lead to anxiety and depression (Øyane, Pallesen, Moen, Åkerstedt, & Bjorvatn, 2013; Parkes, 2015).

Other consequences

Sleep deprivation resulting from the dysregulation of the circadian rhythms impact alertness and psycho-physical performances during day and night shift. Constant sleepiness and fatigue are suggested to be some of the most important variables in work injuries and accidents (Costa, 2010). Evidence also suggests that, under similar working conditions, the risk of an accident is increased by 18 percent in the afternoon shift, and by 30 percent in the night shift (Folkard, 2003).

Due to these negative outcomes caused by shift work on health, various authors have presented suggestions to better cope and adapt to shift work. For example, Knauth (2003) presented recommendations aimed at companies to organize their shift systems better. Some suggestions were:

- Fewer night shifts in succession (maximum of three)
- Avoid fixing night shift
- Fewer morning shifts in succession (maximum of 3)
- Fewer evening shift in succession (maximum of 3)
- Forward rotation is better than backward
- At least two days off between the last night shift and a morning shift
- Avoid a night shift - day off - night shift configuration
• Maximum of five or seven (with some health and safety considerations) consecutive working days
• Avoid shifts of more than eight hours. Acceptable only with some health and safety considerations
• There should be at least more than 11 hours of rest between shifts
• Start the morning shift a little later (e.g. 06:30 hours is better than 06:00 hours)
• End the evening shift a little earlier (e.g. 23:00 hours is better than 24:00 hours)
• End of the night shift as early as possible
• Avoid work on weekends or provide some free weekends with at least two consecutive days off

**Shift work tolerance, recovery and aging**

Shift work tolerance is defined as the capability to adapt in the long term to shift work without suffering adverse consequences, such as sleep problems, fatigue, gastrointestinal disturbances, sleep medication dependence, and mood disturbances, including depression (Reinberg & Ashkenazi, 2008). The concept of shift work tolerance was proposed by Andlauer, Reinberg, Fourre, Battle, & Duverneuil in 1979, and it has been changing over the years. Currently, there is no clear consensus in the literature about the definition of the concept, or how to measure it. Some of the typical strategies that researchers have used to measure shift and night work tolerance include: Subjective questionnaires about the perception of shift work tolerance (Saksvik-Lehouillier, Pallesen, Bjorvatn, Mageroy, & Folkard, 2015), sleep-related problems questionnaires like sleepiness (Cotrim et al., 2017), sleep quality (Parkes, 2015), and sleep duration (van de Ven et al., 2016). Questionnaires have also been used to measure perceived physical health (Castro, Carvalhais, & Teles, 2015), symptoms of affective disorders like anxiety (Øyane et al., 2013), and depression (Jung & Lee, 2015), and psycho-social outcomes like work-family conflict (Willis, O’Connor, & Smith, 2008), and work satisfaction (Axelsson, Åkerstedt, Kecklund, Lindqvist, & Attefors, 2003). Other authors have employed more objective measures such as cognitive performance tests (Tadinac, Sekulic, Hromatko, Mazul-Sunko, & Ivancic, 2014), actigraphy tests (Seo, Matsumoto, Moon, & Hayasaka, 2005), saliva and blood tests to measure cortisol (Bostock & Steptoe, 2013) and inflammatory markers (Viitasalo, Puttonen, Kuosma, Lindström, & Härmä, 2015). Diverse authors nowadays commonly use a combination of these strategies for
their studies. It is not rare to find research which has used clinical or chronobiological measures, along with psychosocial questionnaires, to measure shift work tolerance; for instance, the use of questionnaires to assess for sleep need, sleep duration, sleep loss and fatigue, in combination with a leukocyte count through laboratory testing (Viitasalo et al., 2015).

The different strategies that researchers use today expose the fragmentation of the conceptualization and definition of shift work tolerance. Similarly, need for recovery, another concept used to measure the association between aging and shift work, suffers from the same problem. The need for recovery is defined as the need to recuperate after a work shift, and it is implied that without enough time to recover, over time, it can lead to performance impairment, persistent fatigue, and health complications (Sluiter, van der Beek, & Frings-Dresen, 1999). This variable is categorized by some authors as a distinct approach from tolerance due to the very nature of the its definition, while others researchers have used need for recovery as another strategy to measure shift work tolerance, as two recent reviews did (Blok & de Looze, 2011; Saksvik, Bjorvatn, Hetland, Sandal, & Pallesen, 2011).

Nowadays, due to all the evidence compiled from the last decades, it is well accepted that shift and night work have a negative impact on employees in several health dimensions. Thus, researchers have started to focus on studying other variables to discover the best shift conditions, or how individual differences can mitigate or aggravate tolerance of shift work. The most common individual characteristics studied in the literature are gender, personality traits, chronotype preference, and age (Saksvik et al., 2011).

In terms of chronotype preference, there is a vast amount of evidence that suggests that morning types tolerate better early morning shifts than evening types. On the contrary, evening types have more tolerance to night shift compared to morning types. These differences are due to the phase synchronization of the circadian rhythms with late night (evening types) or early morning activation (morning types) (Juda, Vetter, & Roenneberg, 2013).

With regard to personality traits, flexibility is being associated with better tolerance and recovery from shift work due to more flexible strategies and sleeping habits
to reduce the negative effects of shift work. Neuroticism, on the other hand, is considered a negative variable to shift work tolerance (Costa, 2010)

Gender is also considered a key factor of tolerance to shift work. Studies have reported that women have more difficulty recovering from sleep deprivation and fatigue due to greater responsibilities and commitments with family or children, and worse physical health compared to men (Saksvik et al., 2011)

Regarding age, research has suggested that younger workers have more tolerance to shift work compared to older ones. Shen & Dicker (2008) found that older employees experienced more fatigue, need more time to recover and were less motivated in shift work than younger employees. Similarly, Natvik et al. (2011) showed that that age was significantly and positively associated with a higher score of insomnia and depressive symptoms. Researchers suggested various reasons to explain this effect of aging in tolerance and recovery from shift work:

- Weakening of the circadian system resulting from molecular and functional deterioration in the suprachiasmatic nucleus, which makes it less reactive to external light time signals (Van Someren, 2000)
- Aging is associated with an earlier phasing (morningness) of circadian rhythms (Lieberman, Wurtman, & Teicher, 1989)
- Circadian rhythms of older workers adjust more slowly to consecutive night shifts (Harma, Hakola, Akerstedt, & Laitinen, 1994)
- Sleep duration is reduced in older ages, which increases sleepiness during waking hours (Juda et al., 2013)

Due to these results, Costa & Di Milia (2008) proposed some specific recommendations to support aging shift workers, such as limiting night work after 45-50 years of age, reducing workloads, shortening work hours and/or increasing rest periods, and giving priority for older shift workers to move to day work, among others. These conclusions and recommendations can be found in several studies about the topic, suggesting that the hypothesis about the negative effects of aging in shift work is partially accepted among certain researchers.

Nevertheless, there is also a vast amount of research which has shown no significant difference in tolerance to shift work between younger and older workers.
Furthermore, there are studies that have even suggested the opposite results. In a study with 160 women nurses, no significant difference was found between younger and older workers in terms of sleep quality and insomnia scores (Yazdi, Sadeghniati-Haghighi, Javadi, & Rikhtegar, 2014). Similarly, in a longitudinal study, it was found that older age predicts fewer symptoms of insomnia. Recent reviews have reached similar mixed results, suggesting that today there is not a clear agreement in the literature about the real association between aging and shift work (Blok & de Looze, 2011; Saksvik et al., 2011). Other studies have proposed that the association between aging and shift work is not linear, and that the critical age for shift work intolerance is in middle-age, between 45 and 50 years old. Two recent studies investigating this type of relationship, have found that night shift sleep quality decreases to the lowest point at the ages of 38-42 (Parkes, 2015), and that general sleep problems are more prevalent in middle-aged shift workers (Tucker, Folkard, Ansiu, & Marquié, 2011). The greater difficulty in tolerating shift work by younger workers may be explained by the physiological and social adaptation required in the shift system, which some cannot adequately deal with.

Some of the possible reasons for these conflicting results may be the methodological bias and weaknesses related to the categorization of age, the definition of shift work tolerance, and the healthy worker effect.

Regarding the categorization of age, several studies classified “young” workers and “old” workers depending on the distribution of the sample, and in many cases, this distribution did not represent the total age range of the working population (18-65 years of age in some countries). Thus, it is possible to find studies where “young” workers are those who are under 40, while in other studies “young” could mean 30. Similar situations occur with “older”; in some cases, it could mean more than 50 years old, but in others could mean 30. In the literature, there is no fixed parameter to determine who is a “young” worker or an “older” worker. These issues lead to difficulties in interpreting and comparing results, affecting the possibility of reaching reliable results.

The concept of shift work tolerance suffers from the same problems. As explained earlier, shift work tolerance does not have a consensus definition in the literature and, even less, a homogenous method of measuring it. Additionally, even when researchers use the same strategy (e.g. sleep quality) to measure the difference between younger and older workers and shift work, they may use completely different instruments, like questionnaires or actigraphy. This discrepancy between the different ways of measuring
tolerance to shift work and results has been documented by different studies. Saksvik et al. (2011) found that studies related to the measurement of cognitive performance, motor or work-related tasks, favoured the youngsters above the older workers. On the other hand, shift work tolerance that was measured in terms of cholesterol levels, and shift work related diseases, showed better results for older workers compared to the younger ones. But the author mentioned that these results may be influenced by the healthy worker effect.

The healthy worker effect refers to a selection bias where workers with more tolerance to shift work are more likely to stay working, while the more intolerant shift workers leave (Li & Sung, 1999). This means that when a researcher assesses older employees, the assessment is made only on the healthy workers who stayed. Thus, this sample will have better health parameters than the population of the same range of age. However, not all results can be explained by this phenomenon; therefore, it is necessary to find other possible alternatives. Perhaps work experience favours the formulation of better strategies for coping with the demands of shift work. To control this possible effect, it is necessary to carry out longitudinal studies.

Researchers have emphasized the need for longitudinal studies to more accurately determine the effect of aging and shift work, but to date, only a few studies in the area have been conducted. In past reviews, considering periods between 1980 and 2009, only four longitudinal studies were found, which raises the need to carry out this type of research to advance the understanding of the relationship between aging, shift work and tolerance (Blok & de Looze, 2011; Saksvik et al., 2011).

Conclusion

It is clear that the general and working population is aging, and that they are going to continue working after 65 years of age in the future due to the rise in retirement age in most industrialized countries. It is also a fact that countries and companies will have to improve their policies for better retention, training, and the health of the old workers; and as a society, we must improve our prejudices and stereotypes about this population. One of these stereotypes is that the old people have less tolerance to shift work than younger ones, and this review has found evidence that supports this notion. However, there is also evidence that there is no significant relationship between age and shift work, and even
some authors suggest that under certain conditions older workers tolerate this shift system better than younger workers. What is more certain, despite also having contrary evidence, is that shift work generates major problems in health, both physical and mental, and that actions have to be taken to mitigate its effect. Due to the evidence in the current literature, taking actions, such as not allowing old workers to perform work shifts seems more like discrimination than a policy with a scientific basis. However, because aging may present problems for some workers and not others, perhaps general suggestions (not impositions), flexibility and greater support for this population can facilitate better performance, satisfaction, and health. Finally, due to mixed results in primary research and reviews, additional analysis is needed to determine the current status of the topic, and it is also necessary to improve some methodological and design aspects in future studies to further advance the understanding of the relationship between aging and shift work.
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PART B: Effects of aging on tolerance and recovery from shift work: A systematic review

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Abstract

This paper reviews evidence published on the effect of ageing on tolerance and recovery from shift work since 2011. The associations between age and shift work have been reviewed through the effects on affective disorders, health, performance and sleep-related issues. The results were mixed, from 25 articles reviewed: 12 studies suggested better shift work tolerance in certain variables among younger workers, eight studies reported the opposite results, while 12 studies found no significant correlation between age and shift work by the variables examined. Additionally, two studies reported no linear relationship, where the middle-age group was less tolerant to shift work compared to younger and older workers. The review also showed a lack of consensus about the definition and way of measuring shift work tolerance. Based on these findings, theoretical, methodological, and practical implications were discussed.
**Introduction**

Over the last two decades, the study of the effects of aging on the work force has been a major topic for researchers and policy makers. This increased interest may be due to the shift in demographic variables, like the aging of the general work force and the low birth rates in industrialised countries. Due to technological advances in medicine, better working and living conditions, global life expectancy at birth has increased by five years between 2000 and 2015 (WHO, 2015). In the past, most of the work force consisted of young workers. However, it is projected that this demographic structure will change, and the larger mass of employees will be made up of middle-aged and older workers. Figures from the United States and the European Union show a constant increase in the mean population age compared to the past two decades, and it is projected to continue rising. In the United States, the labour force aged 55 and above increased from 14.3 percent to 20.9 percent between 2002 and 2012, and it is projected to continue increasing to 25.6 percent by 2022 (Toossi, 2013). Similarly, Giannakouris (2008) showed that in the European Union, the population mean age is projected to increase from 40.4 to 47.9 between 2008 and 2060. Because of the possible effects that these changes might have, countries and companies should generate new policies to secure improved employment, performance, well-being, and health for older workers (Bourn, 2007; Cloostermans, Bekkers, Uiters, & Proper, 2014; Costa & Di Milia, 2008). Another relevant issue that researchers point out regarding the aging work force is its capability, which could be impaired, to tolerate and recover from today’s demanding rhythms and schedules, like shift work (Blok & de Looze, 2011; Saksvik, Bjorvatn, Hetland, Sandal, & Pallesen, 2011).

The European Union, through the European Work Time Directive, define shift work as “any method of organising work in shifts whereby workers succeed each other at the same work stations according to a certain pattern, including a rotating pattern, and which may be continuous or discontinuous, entailing the need for workers to work at different time over a given period of days or weeks” (European Commission, 2003, p. 2). This type of work schedule has become particularly popular in the health, transport and communication, and manufacturing industries due to the need for continuous work, competitiveness, and high standards and requirements demanded by customers. Records show that approximately 14 percent of the labour force in the United Kingdom do shift work (Office of National Statistics, 2011). This figure is similar to the one of the United
States (15 percent) and the European Union (17 percent) (Bureau of Labor Statistics, 2005; Parent-Thirion et al., 2012).

Despite the acceptance and regulations of shift work, there are an increasing number of studies that associate shift work with different issues, like cardiovascular disease (Puttonen, Härmä, & Hublin, 2010), gastrointestinal disturbances (Knutsson & Bøuggild, 2010), metabolic disorders (Nakata et al., 2004), cancer (International Agency for Research on Cancer, 2007), pregnancy issues (Mozurkewich, Luke, Avni, & Wolf, 2000), increasing risk of labour accidents (Folkard, 2003), social difficulties (Strazdins, Clements, Korda, Broom, & D’Souza, 2006), depressive symptoms (Nakata et al., 2004), poorer life satisfaction (Kaliterna, Prizmic, & Zganec, 2004), fatigue (Chen, Davis, Daraiseh, Pan, & Davis, 2014), and sleep problems (Yazdi, Sadeghniiat-Haghighi, Javadi, & Rikhtegar, 2014). Sleep difficulties, like insomnia, sleep disruption, and sleepiness are some of the most common issues that shift workers may face (Åkerstedt & Wright, 2009).

Shift and night work requires employees to live and work according to a different pattern compared to day workers, which affects the internal biological synchronicity. The perturbation or inversion of the sleep-wake cycle, linked with the modified activity-rest pattern, can interfere with the circadian system. Circadian rhythms are physiological and behavioural cycles with a recurring periodicity of about 24 hours, which are driven by the biological pacemaker, the suprachiasmatic nucleus (SCN) located in the hypothalamus, and synchronised by environmental cues or stimuli (e.g. light/dark cycle) called zeitgebers (Costa, 2010; Zee, Attarian, & Videnovic, 2013). These rhythms control a variety of internal biological processes, like the sleep-wake cycle, eating, hormone secretion, body temperature, glucose secretion and homeostasis. Numerous, if not all, of the negative issues of shift and night work are linked to the dysregulation of the circadian system and sleep patterns. The impact and effect of this dysregulation depend, in part, on how tolerant a person is.

Andlauer, Reinberg, Fourre, Battle, & Duverneuil (1979) conceptualized the term shift work tolerance, and defined it as the capability to adapt in the long term to a shift work schedule without suffering adverse consequences (shift work intolerance) like sleep alteration, fatigue, gastrointestinal difficulties, sleep medication dependence, and mood disturbances, including depression (Reinberg & Ashkenazi, 2008). However, there is no clear consensus regarding shift work tolerance because the concept in the literature has been defined and measured in different ways. Some of the measurements that researchers
use include: subjective evaluation questionnaires and tests about shift work tolerance (Saksvik-Lehouillier, Pallesen, Bjorvatn, Mageroy, & Folkard, 2015), sleep-related problems (Larsgård & Saksvik-Lehouillier, 2017), affective disorder symptoms like depression (Jung & Lee, 2015) and anxiety (Parkes, 2015), performance during and after shifts (Tadinac, Sekulic, Hromatko, Mazul-Sunko, & Ivancic, 2014), and physical health (Castro, Carvalhais, & Teles, 2015). Other researchers choose to use more objectives types of measurements like cortisol (Bostock & Steptoe, 2013), and inflammatory markers (Viitasalo, Puttonen, Kuosma, Lindström, & Härmä, 2015). Usually, these two different types of measures (Clinical and chronobiological vs psychological and social questionnaires) complement each other, and they are being used together to assess shift work tolerance on employees (Reinberg & Ashkenazi, 2008). For example, Saksvik-Lehouillier, Pallesen, Bjorvatn, Mageroy, & Folkard (2015) explored a more comprehensive definition of shift work by including not only the typical shift work tolerance variables, like insomnia, fatigue sleepiness, anxiety and depression, but also including physical health, social problems, mental health, and alcohol dependency. The conclusion of this study was the need for a new definition of shift work tolerance that includes a more integrated approach.

Another concept related to shift work tolerance often named in the literature is need for recovery. This variable refers to the need to recuperate after a work shift, and it is implied that without enough time to recover, it can lead to performance impairment, persistent fatigue, and health complications (Sluiter, van der Beek, & Frings-Dresen, 1999). Some authors consider need for recovery a different phenomenon from shift work tolerance, while others consider it as one of many variables that can be used to evaluate shift work tolerance in employees. In terms of simplicity, shift work tolerance is going to be referred to as a broader concept, which includes need for recovery. This strategy has also been used in other reviews on this topic (Blok & de Looze, 2011; Saksvik et al., 2011).

Research shows that some individual characteristics can moderate the consequence of shift work tolerance. The most common individual variables studied in the literature are gender, personality traits, chronotype preference, and age. (Saksvik et al., 2011). Regarding age, some studies suggest that older employees are more intolerant to shift work than younger ones. For example, Chan (2009) found that insufficient sleep was positively associated with older age. Similarly, Shen & Dicker (2008) showed that
older workers experienced more fatigue, needed more time to recover and were less motivated in a shift work schedule compared to younger workers. There are several factors that are suggested to explain the association of aging with less ability to adjust to shift work: (1) weakening of the circadian system resulting from molecular and functional deterioration in the suprachiasmatic nucleus, which makes it less reactive to external light time signals (Van Someren, 2000); (2) aging is associated with an earlier phasing (morningness) of circadian rhythms (Lieberman, Wurtman, & Teicher, 1989); (3) circadian rhythms of older workers adjust more slowly to consecutive night shifts (Harma, Hakola, Akerstedt, & Laitinen, 1994); and (4) sleep duration is reduced in older ages, which increased sleepiness during waking hours (Juda, Vetter, & Roenneberg, 2013).

However, there are also a significant number of studies that found no significant difference in terms of shift work tolerance between older and younger workers. Moreover, some research even showed that older workers tolerate shift and night work better than younger ones. Burch et al. (2009) found that old age was associated with optimal job performance, measured by self-reported problems with sleep, fatigue, attitudes to work, health, lifestyle and well-being, schedule adaptation, and sleep quality. Furthermore, Winwood, Winefield, & Lushington (2006) showed that older workers (over 55 years) reported less chronic fatigue and better recovery than younger workers. These studies are not isolated cases, as one recent review suggested that there is no evidence about shift work problems with increasing age (Blok & de Looze, 2011), and another one reached inconclusive results (Saksvik et al., 2011).

With no clear consensus regarding this topic, and with several empirical articles published since the last reviews (2011), the aim of this study is to examine recent literature, between 2011-2017, for answers about the association between age and shift work tolerance.
Methods

This review was based on a systematic search and selection process. For this study, the schedules that were considered as shift work were: irregular shift work, fixed shift work, rotating shift work and night work. These work schedules were chosen as they are more likely to show any differences in circadian dysregulation and adjustment by workers with certain individual characteristics, for example, age. The review did not include the terms: on call shift, overtime, occasional shift, flex-work, and part-time work, as these components of the work schedule may represent variations in the working time pattern and/or additional hours of work, and not a focus on what is defined in terms of hours of work in the contract of employment.

Search methods

Sources

A systematic search was conducted in four databases from 10th May to 25th July 2017 to retrieve articles. Searches were performed within the databases of Medline, PsycINFO, Web of Science, and ScienceDirect for studies published between 2011 and July 2017. Furthermore, to recover additional relevant literature, the reference list of the identified articles was examined.

Search strategy

Since this review was focused on the relationship between age and shift work in term of tolerance, using the changes in the circadian rhythms as a framework, the search was conducted using a combination of groups formed by different keywords related to those topics. Additionally, the Boolean operators AND, and OR were used along with the search terms. Table 1 shows the search strategy used in the Medline database. Similar strategies were used for PsycINFO, Web of Science and ScienceDirect. Results were restricted to English language and from 2011 onwards.
Table 1 Search strategy used for Medline via Ovid

<table>
<thead>
<tr>
<th>Limits: Human, English language, and publication year from 2011 onwards</th>
</tr>
</thead>
<tbody>
<tr>
<td>“work schedule” OR “shift work” OR shiftwork OR shift-work OR nightwork OR “night work”</td>
</tr>
<tr>
<td>AND age OR ageing OR aging OR elderly OR older</td>
</tr>
<tr>
<td>AND circadian OR “circadian rhythm”</td>
</tr>
<tr>
<td>AND tolerance OR tolerant OR intolerance OR intolerant OR recover OR recovery</td>
</tr>
</tbody>
</table>

Study eligibility and selection

The eligibility and selection process consisted of two main phases. Firstly, the articles were examined for suitability based on their titles and abstracts. Secondly, the full text of the study that met the inclusion criteria and exclusion criteria presented below was retrieved for deeper evaluation.

Inclusion and exclusion criteria

To be included in this review, the study had to satisfy all following inclusion criteria:

1. The study was published in English
2. Published since 2011
3. The relationship between age, shift work tolerance, and circadian rhythms needed to be addressed
4. The study had to be in the context of shift work:
   - Irregular shift work
   - Fixed shift work
   - Rotating shift work
   - Night work
5. Original quantitative empirical research with full-text available
6. Field studies in working human population

Articles were excluded if one of the following criteria were met:

1. Work schedule:
   - On call shift
   - Overtime
2. Source:

- Reviews and meta-analysis
- Books
- Conference proceedings

Results

Search and selection

Figure 1 presents the Prisma flow diagram adopted in this study. A total of 820 articles were extracted, and after removing the duplicates, 441 titles and abstracts were selected for screening. After applying the eligibility criteria, the full text of 76 articles was read, and 25 papers were selected to be included in the present review. The main reasons for exclusion of studies in the eligibility phase were lack of information about the relationship between age and shift work tolerance, the type of shift (e.g. on night call, occasional shift), and type of article (e.g. review).

Summary of the included articles

Details on each paper of authorship, design, shift schedule characteristics, sample and main results were summarised as presented in Table 2. All studies covered the relationship between age and shift work tolerance, but the measures used in each article differ greatly from each other. The studies represent research developed across 14 different countries in Europe, Asia, North America, Australia, and the Middle East. The majority of participants were women, and Norway was the country with more articles published. In term of jobs and professions, nurses were a tendency in the sample. The sample size varied from small (26) for cross-sectional studies, to very high (28.041) as in the case of cohort studies, and seven out of 25 studies had a population of 1000 or more people. From the 25 articles reviewed, 20 were categorized as cross-sectional studies (1, 3, 5-10, 12-20, 22-24), and six were classified as longitudinal studies (2, 4, 10, 11, 21, 25). As can be noted, one paper in particular (10), was classified as both cross-sectional and longitudinal at the same time. The study 25 was the longest research with a period of
The vast majority used self-administered questionnaires, except studies 10 and 11 (laboratory tests), 12 (semi-structured interviews), and 14 (psychological instruments). The relationship between age and shift work tolerance was examined using sleep related variables (nineteen studies), fatigue (five studies), depression (three studies), anxiety (two studies), well-being (one study), physical health (two studies), inflammatory response (one study), diabetes (one study), cognitive performance (one study), and cortisol (one study).

The results of the interaction between age and shift work tolerance are summarised in Table 3. In total, 20 different concepts were identified, that depending on the case, show no relationship or a significant interaction between aging and shift work tolerance.
Affective disorders

Anxiety

Two articles reported no significant association between age and shift work tolerance regarding anxiety symptoms. Parkes (2015) found no difference in anxiety symptoms and age in the male population during a 12-hour rotation shift system. Similar results were obtained by Øyane, Pallesen, Moen, Åkerstedt, & Bjorvatn (2013), but with a sample of 90% women, and on a night shift schedule.

Depression

Three studies showed a significant relationship, but with mixed results. One article showed a negative correlation between age and shift work tolerance, while the other two studies showed positive results. Jung & Lee (2015) found that with increasing age, nurses reported fewer symptoms of depression compared with younger ones on a rotating shift schedule. On the other hand, Natvik et al. (2011) indicated that age was significantly and positively associated with higher levels of depressive symptoms in nurses in a rotating shift system. Øyane et al. (2013) also found that age was positively related to depression scores, but only in nurses with less than three years of night work. All three studies used nurses as a sample, and most of them were female.

Health and well-being

Cortisol

Only one article studied cortisol to detect differences in age and shift work tolerance. Using a sample of male pilots, Bostock & Steptoe (2013) found no association between cortisol levels and age in a 2-shift rotating schedule.

Diabetes

In a cohort sample of 28,041 African-American women, Vimalananda et al. (2015) reported that after working on night shift for ten years or more, women aged <50 had 39% higher risk of diabetes compared to just 17% in women age >50.

Fatigue

Four out of five articles showed no difference in fatigue between older workers and younger ones (Castro, Carvalhais, & Teles, 2015; Jung & Lee, 2015; Viitasalo,
Puttonen, Kuosma, Lindström, & Härmä, 2015; Øyane et al., 2013). However, Courtney, Francis, & Paxton (2013) found, after a regression analysis, that younger workers suffer higher fatigue than older workers.

**Inflammatory response**

No difference was found in leukocyte count between younger (<45) and older (>45) male employees working on shift schedules (Viitasalo et al., 2015).

**Physical health**

Castro et al. (2015) showed no significant relationship between age and health variables in cabin crew members during irregular shift work. While, Saksvik-Lehouillier, Pallesen, Bjorvatn, Mageroy, & Folkard (2015) detected older nurses had more physical health complaints than younger ones.

**Well-being**

Just one study showed results for the interaction between age and well-being in a shift work setting. It was shown that age was negatively related to well-being in a sample of nurses on a rotating three-shift schedule (Saksvik-Lehouillier et al., 2015).

**Performance**

**Cognitive performance**

Tadinac, Sekulic, Hromatko, Mazul-Sunko, & Ivancic (2014) showed, in a group of anesthesiologists, that after a 24-hour shift, the cognitive performance was worse for older residents compared to the younger ones.
<table>
<thead>
<tr>
<th>No</th>
<th>Authors (Date)</th>
<th>Design</th>
<th>Shift schedule</th>
<th>Sample</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Cotrim et al. (2017)</td>
<td>Cross-sectional study. Questionnaire administered once on paper between November and December of 2011.</td>
<td>Rotating three-shift schedule including morning, afternoon, and night shift.</td>
<td>97 male railway controllers. Mean age 44.80 years, range 34-57 years. (Portugal)</td>
<td>Morning shift sleepiness decreases with age. Age did not appear as a predictive variable for afternoon and night sleepiness.</td>
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<td>2</td>
<td>Larsgård &amp; Saksvik-Lehouillier (2017)</td>
<td>Longitudinal study. Questionnaire administered twice via email. Once in January 2013 (T1) and once in June-July 2013 (T2).</td>
<td>Different shift schedules, including only night shifts, rotating three-shifts and rotating two-shifts including night.</td>
<td>96 municipality employees from the health sector, social services, and others. 62 women and 24 men. Mean age 37 years, range 20-65 years. (Norway)</td>
<td>Age was negatively related to symptoms of insomnia in T2. Older age predicts fewer symptoms of insomnia.</td>
</tr>
<tr>
<td>3</td>
<td>van de Ven et al. (2016)</td>
<td>Cross-sectional study. Questionnaire administered once. Paper and Web-based versions.</td>
<td>Different shift schedules including rotating morning, evening, and night shifts.</td>
<td>650 blue collar shift workers. Categories for age ≤ 35, 36-45, 46-55, ≥ 55. (Netherlands)</td>
<td>Older workers (≥ 55 years) report shorter sleep duration compared to younger workers (≤ 35). No significant association were found for age with disturbed sleep, awakening complaints, and need for recovery.</td>
</tr>
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<td>4</td>
<td>Bjorvatn, Mageroy, Moen, Pallesen, &amp; Waage (2015)</td>
<td>Longitudinal cohort study. First data collection was conducted in 2008/2009 (Wave 1) with annual follow-ups. The fourth data collection took place in 2012 (Wave 4)</td>
<td>Different shift schedules including night shift, two-shift and three-shift rotation.</td>
<td>2198 nurses. 1987 females and 201 males. Mean age in wave 1 was 31.9 years, range 21-63 years. (Norway)</td>
<td>Age was negatively associated with the prevalence of confusional arousal (Parasomnia).</td>
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<tr>
<td></td>
<td>Study Authors and Year</td>
<td>Study Design</td>
<td>Questionnaire Administration</td>
<td>Working Schedule</td>
<td>Participants</td>
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<td>5</td>
<td>Castro, Carvalhais, &amp; Teles (2015)</td>
<td>Cross-sectional study. Questionnaire administered once. The questionnaire was available in the airline headquarters, and the cabin crew was invited to answer it during the month of February 2012.</td>
<td>Irregular working hours with night shifts.</td>
<td>73 cabin crew members, 39 females and 34 males. Mean age 27.6 years old, range 20-37 years old. Categories for age younger one (20-27 years old) and the older one (28-37 years old). (Portugal)</td>
<td>No significant relationship between age, fatigue, and health variables.</td>
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<td>6</td>
<td>Jung &amp; Lee (2015)</td>
<td>Cross-sectional study. Questionnaire administered once in June/July 2013.</td>
<td>Rotating three-shift schedule. Morning, evening, and night shifts.</td>
<td>660 nurses. 98% female. Mean age 27.5 years. (South Korea)</td>
<td>Age showed a significant negative relation to depression. No statistical differences in insomnia or fatigue.</td>
</tr>
<tr>
<td>7</td>
<td>Parkes (2015)</td>
<td>Cross-sectional study. Questionnaire administered once.</td>
<td>12-hour rotation shifts. Day shifts, night shifts, and leave weeks.</td>
<td>775 male personnel. Mean age 39.9 years, range 19-64 years. (Europe)</td>
<td>Age was negatively related to day and leave shifts sleep duration, no effect on night shifts. Night shifts sleep quality decreased from the youngest age to ages 38-42 and then gradually increased again for ages &gt;42 years. Day and Leave shifts sleep quality was unrelated to age. No relationship found between age and anxiety.</td>
</tr>
<tr>
<td>8</td>
<td>Saksvik-Lehouillier, Pallesen, Bjorvatn, Mageroy, &amp; Folkard (2015)</td>
<td>Cross-sectional study. Questionnaire administered once.</td>
<td>Rotating three-shift schedule. Morning, evening, and night shifts.</td>
<td>1,529 nurses. 1,389 women, 133 men. Mean age 31 years, range 21-62 years. (Norway)</td>
<td>Age was negative and significantly related to well-being (social functioning, mental health, vitality, insomnia, fatigue, anxiety and depression), and physical health (good health and SWT).</td>
</tr>
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<td>9</td>
<td>Taniyama, Nakamura, Yamauchi,</td>
<td>Cross-sectional study. Questionnaire administered once.</td>
<td>Rapidly rotating shifts which included morning.</td>
<td>556 male workers (363 shift workers). Mean age 42.0 years, range 20-62 years. (Japan)</td>
<td>No significant difference was found between the group with shift work disorder and the one without shift work disorder in term of age.</td>
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<tr>
<td></td>
<td>Authors and Year (Reference)</td>
<td>Study Design</td>
<td>Shift Types</td>
<td>Number of Participants</td>
<td>Follow-up</td>
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<td>10</td>
<td>Viitasalo, Putonen, Kuosma, Lindström, &amp; Härmä (2015)</td>
<td>Cross-sectional and longitudinal study. The baseline data were collected from 2006 to 2008 and included physical examination, laboratory test and questionnaires. The follow-up to 130 shift workers was completed two and a half years later during 2009 and 2010.</td>
<td>Different types of shift schedules. Day work, two-shift work, fast forward-rotating three-shift work, slower backwards-rotating three-shift work, flexible three-shift work.</td>
<td>319 male shift workers. 453-day workers as a reference. Two age groups, &lt;45 and &gt;45 years. (Finland)</td>
<td>In the forward-rotating three-shift work, older employees reported longer sleep need and sleep time compared to the younger group. No significant difference between sleep loss and daytime fatigue. In term of leukocyte count, the age differences in the inflammatory system were non-significant.</td>
</tr>
<tr>
<td>11</td>
<td>Vimalananda et al. (2015)</td>
<td>Longitudinal Cohort study. Time between 2005 and 2013. Questionnaires and laboratory test were analysed.</td>
<td>Night shift work.</td>
<td>28.041 African American women. Age range 21-69 years. Two categories for age &lt;50 and &gt;50. (USA)</td>
<td>Working night shifts for ≥ ten years relative to never working the night shift was associated with 39% higher risk of diabetes among women aged &lt;50 years compared with just 17% greater risk in older women age ≥ 50 years.</td>
</tr>
<tr>
<td>12</td>
<td>Costa, Anelli, Castellini, Fustinoni, &amp; Neri (2014)</td>
<td>Cross-sectional study. Semi-structured interview and questionnaire.</td>
<td>3x8 rotation shift (morning, afternoon and night), and 2x12 rotation shift (Day and night work)</td>
<td>294 nurses. 72.6% were women. Mean age 33.8 years.</td>
<td>Age was positively associated with sleep disturbances in nurses engaged in the 3x8 shift, but not in the 2x12 shift.</td>
</tr>
<tr>
<td>13</td>
<td>Loudoun, Muurlink, Peetz, &amp; Murray (2014)</td>
<td>Cross-sectional study. Questionnaire administered once by mail.</td>
<td>Night shifts and rotations shifts.</td>
<td>2640 workers. 96.3% males and 3.1% females. Mean age 46.8 years. 36% of the sample were aged</td>
<td>For older workers aged 50 or more, low shift control results in more disturbances.</td>
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<tr>
<td>No.</td>
<td>Author(s)</td>
<td>Study Design</td>
<td>Questionnaire/Psychological Instruments</td>
<td>Shift Schedule</td>
<td>Sample Description</td>
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<td>14</td>
<td>Tadinac, Sekulic, Hromatko, Mazul-Sunko, &amp; Ivancic (2014)</td>
<td>Cross-sectional study. Questionnaire and psychological instruments administered twice.</td>
<td>24 hours shift.</td>
<td>26 anesthesiology residents. 6 males, 20 females. Mean age 29.9 years, range 26-35 years. (Croatia)</td>
<td>The magnitude of the interference (cognitive performance) was correlated positively with age only after the shift, but not before.</td>
</tr>
<tr>
<td>15</td>
<td>Yazdi, Sadeghniiat-Haghighi, Javadi, &amp; Rikhtegar (2014)</td>
<td>Cross-sectional study. Questionnaire administered once.</td>
<td>8 hours shift work. Three groups: night workers, rapid rotating shift work, and slow rotating shift work.</td>
<td>160 women nurses. Mean age 31.3 years, range 23-41 years. (Iran)</td>
<td>Aging has no effect on sleep quality and insomnia in nurses.</td>
</tr>
<tr>
<td>16</td>
<td>Bostock &amp; Steptoe (2013)</td>
<td>Cross-sectional study. Questionnaire administered once, and saliva samples collected six times over the day on two consecutive days for each of 3 shift conditions.</td>
<td>2-shifts rotation schedule. Early morning, rest, and late shift.</td>
<td>30 male pilots. Mean age 39.4 years. (United Kingdom)</td>
<td>There was no association between cortisol indicators and age.</td>
</tr>
<tr>
<td>17</td>
<td>Courtney, Francis, &amp; Paxton (2013)</td>
<td>Cross-sectional study. Questionnaire administered once</td>
<td>roster cycle that includes night shift.</td>
<td>150 paramedics. 117 males and 31 females. (Australia)</td>
<td>Regression analysis model identified that age was negatively associated with chronic fatigue.</td>
</tr>
<tr>
<td>18</td>
<td>Juda, Vetter, &amp; Roenneberg (2013)</td>
<td>Cross-sectional study. Questionnaire administered once between March 2006 and</td>
<td>Three-Shift system. Morning, evening, and night shift.</td>
<td>238 shift workers. 83 women and 155 men. Mean age 38.8 years. (Germany)</td>
<td>There is a significant age effect on sleep duration. With increasing age, participants slept shorter. No significant relationship between age and sleep disturbances.</td>
</tr>
<tr>
<td></td>
<td>Study Description</td>
<td>Participants</td>
<td>Results</td>
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<td>19</td>
<td>Øyane, Pallesen, Moen, Åkerstedt, &amp; Bjorvatn (2013) Cross-sectional study.</td>
<td>Night shift work.</td>
<td>2059 nurses. 90.6% were women. Mean age 33.1 years, range 21-63 years.</td>
<td>Age was positively associated with depression score in nurses with less than three years of night work experience. Age was negatively related to sleepiness in nurses with at least three years of night work. No significant relationship between age and anxiety score, insomnia score, and fatigue score.</td>
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<td></td>
<td>Questionnaire administered once via mail between December 2008 and March 2009.</td>
<td></td>
<td>(Norway)</td>
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<tr>
<td>20</td>
<td>Flo et al. (2012) Cross-sectional study.</td>
<td>Different shift schedules including rotation shifts and night shifts.</td>
<td>1968 nurses. 90.2% were females. No SWD group, mean age was 32.8 years, and SWD group mean age was 33.7 years. (Norway)</td>
<td>Age was positively associated with symptoms of shift work disorder (including insomnia and sleepiness) in the adjusted analysis.</td>
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<td>Questionnaire administered once via mail during the winter 2008/2009.</td>
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<td>21</td>
<td>Saksvik-Lehouillier et al. (2012) Longitudinal study.</td>
<td>Rotating three-shift schedule.</td>
<td>642 female nurses. Mean age at T1 was 32.3 years. (Norway)</td>
<td>Age was positively related to sleepiness at T2 when controlling for sleepiness at T1. Older workers may have lower SWT than younger ones.</td>
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<tr>
<td></td>
<td>Questionnaire administered twice, 2008/2009 (T1) and in 2009/2010 (T2) via mail.</td>
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<td>22</td>
<td>Demir Zencirci &amp; Arslan (2011) Cross-sectional study.</td>
<td>8 hours rotating shifts, morning, evening, and night shift.</td>
<td>483 female nurses. Mean age 30.41 years. (Turkey)</td>
<td>Age was a Nonsignificant risk factor of poor sleep quality.</td>
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<td></td>
<td>Questionnaire administered once between July and September 2008</td>
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<td>23</td>
<td>Kageyama, Kobayashi, &amp; Abe-Gotoh (2011) Cross-sectional study.</td>
<td>Rotating shift schedule with day, evening and night shifts.</td>
<td>185 male shift workers. Age provided by categories: -24 years or below: 15, 25-29 years: 26, 30-34 years: 45, 35-39 years: 44, 40 years or above: 27. (Japan)</td>
<td>There is no significant relationship between sleepiness during night shifts (SNS) and age.</td>
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<td>Questionnaire administered once in September 2007.</td>
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<td></td>
<td>Study Authors</td>
<td>Study Type</td>
<td>Schedule and Timing</td>
<td>Sample Size</td>
<td>Results</td>
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<tr>
<td>24</td>
<td>Natvik et al. (2011)</td>
<td>Cross-sectional study.</td>
<td>Rotating two or three shifts schedule.</td>
<td>1505 female nurses. Mean age two shift workers 33.9 years, mean age three shift workers 32.2 years. (Norway)</td>
<td>Age was significantly and positively associated with insomnia score. Also, age was significantly associated with higher levels of depressive symptoms.</td>
</tr>
<tr>
<td>Variable</td>
<td>Nº Article</td>
<td>Relationship between age and shift work</td>
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<tr>
<td><strong>Affective disorders</strong></td>
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<tr>
<td>Anxiety</td>
<td>7, 19</td>
<td>No significant relationship</td>
<td></td>
<td></td>
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<tr>
<td>Depression</td>
<td>6, 19, 24</td>
<td>Significant relationship</td>
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<tr>
<td><strong>Health and well-being</strong></td>
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<tr>
<td>Cortisol</td>
<td>16</td>
<td>No significant relationship</td>
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<td></td>
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<tr>
<td>Diabetes</td>
<td>11</td>
<td>Significant relationship</td>
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<tr>
<td>Fatigue</td>
<td>5, 6, 10, 17, 19</td>
<td>Four articles showed no significant relationship (5, 6, 10 and 19), and one article presented a significant interaction (17)</td>
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<tr>
<td>Inflammatory response</td>
<td>10</td>
<td>No significant relationship</td>
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<td>5, 8</td>
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<tr>
<td>Well-being</td>
<td>8</td>
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<tr>
<td>Cognitive performance</td>
<td>14</td>
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<td><strong>Sleep</strong></td>
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<tr>
<td>Awakening complaints</td>
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<td></td>
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<tr>
<td>Disturbed sleep</td>
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<td>Two articles showed no significant relationship (3 and 18), and the other two articles presented a significant interaction (12 and 13)</td>
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<tr>
<td>Insomnia</td>
<td>2, 6, 15, 19, 24</td>
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<tr>
<td>Need for recovery</td>
<td>3</td>
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<tr>
<td>Need of sleep</td>
<td>10</td>
<td>Significant relationship</td>
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<tr>
<td>Parasomnia</td>
<td>4</td>
<td>Significant relationship</td>
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<td>Shift work disorder</td>
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<td>3, 7, 10, 18</td>
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<tr>
<td>Sleep loss</td>
<td>10</td>
<td>No significant relationship</td>
<td></td>
<td></td>
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<tr>
<td>Sleep quality</td>
<td>7, 15, 22, 25</td>
<td>Two articles showed no significant association (15 and 22), and the other two presented a significant interaction (7 and 25)</td>
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</table>

*The numbers represent the number of the studies in table 2*
Sleep

Awakening complaints

No significant association was found for age and awakenings complaints in a sample of blue collar shift workers (van de Ven et al., 2016).

Disturbed sleep

A mixed result with two articles showing no significant relationship between age and disturbances in sleep, and two studies presenting a significant interaction. The studies of Van de Ven et al. (2016) and Juda, Vetter, & Roenneberg (2013) presented no significant association for age and disturbed sleep. On the other hand, Costa, Anelli, Castellini, Fustinoni, & Neri (2014) found that older nurses suffer more sleep disturbances, but only in a 3x8 shift system, and not in a 2x12 system. Similarly, Loudoun, Muurlink, Peetz, & Murray (2014) found that older shift workers (50 years old or more) have more sleep disturbance compared to younger workers only if they experience low shift control.

Insomnia

Three studies showed no significant association between aging and insomnia symptoms in samples of nurses (Jung & Lee, 2015; Yazdi, Sadeghniiat-Haghighi, Javadi, & Rikhtegar, 2014; Øyane et al., 2013), and two studies showed significant interaction but with different directions. In a longitudinal study, Larsgård & Saksvik-Lehouillier (2017) found that older age predicts fewer symptoms of insomnia in shift workers. On the other hand, Natvik et al. (2011) showed that age was positively associated with an insomnia score in female nurses.

Need for recovery

One study found no significant association between age and need for recovery in a sample of blue collar shift workers (van de Ven et al., 2016).

Need of sleep

Viitasalo et al. (2015) found that in a forward-rotating three-shift system, older (45 years old and more) male shift workers reported longer sleep need compared to the younger group (less than 45 years old).
**Parasomnia**

In a longitudinal cohort study on nurses, Bjorvatn, Magerøy, Moen, Pallesen, & Waage (2015) found that age was negatively associated with the prevalence of parasomnias.

**Shift work disorder**

Mixed results. The article of Taniyama, Nakamura, Yamauchi, Takeuchi, & Kuroda (2015) showed no significant difference in term of age between the group of male shift workers with shift work disorder, and the one without it. However, Flo et al. (2012) found that age was positively associated with symptoms of shift work disorder.

**Sleepiness**

In a sample of male shift workers, Kageyama, Kobayashi, & Abe-Gotoh (2011) found no significant relationship between sleepiness during night shift and age. Saksvik-Lehouillier et al. (2012) showed that older nurses scored higher in sleepiness scores than younger ones. However, Cotrim et al. (2017) found that morning shift sleepiness decreased with age, but no significant interaction was found for afternoon and night sleepiness. Similarly, Øyane et al. (2013) showed that older nurses scored lower in sleepiness, only when they have at least three years of experience on the night shift.

**Sleep duration**

Mixed results, but with more evidence showing that younger shift workers sleep more. In a forward-rotating three-shift system, older workers reported longer sleep time compared to younger ones (Viitasalo et al., 2015). However, van de Ven et al. (2016) found that older workers (50 years old or more) reported shorter sleep duration compared to younger workers (35 years old or less). Similarly, Juda et al. (2013) showed that with increasing age, shift workers slept shorter. Additionally, Parkes (2015) also found that age was negatively associated with sleep duration, but only on day and leave shift. No effect was found for the night shift.

**Sleep loss**

Just one study about this variable, and showed no significant relationship between age and sleep loss in male shift workers (Viitasalo et al., 2015).
Sleep quality

Yazdi et al. (2014) and Demir Zencirci & Arslan (2011) found no significant association between aging and sleep quality in female nurses on shift systems. However, Parkes (2015) and Tucker, Folkard, Ansiau, & Marquié (2011) showed a nonlinear relationship among sleep quality and age. In the case of Parkes, night shifts sleep quality decrease at the lowest point at the age of 38-42 years old. While Tucker showed that sleep quality problems were most prevalent in the middle age range of the participants (42-52 years old).

Discussion

Main results

The objective of this review was to examine recent studies on the relationship between age and shift work, and the different variables that researchers commonly use to investigate this relationship. Overall, the results are conflicting. With the information gathered from this work, it is not possible to provide a conclusion to the topic at hand because there is no consensus in the literature regarding the effect or impact that aging may have on tolerance and recovery from shift work.

From the articles reviewed, 12 showed some evidence that younger workers have better tolerance to shift work compared to older ones. These results support the hypothesis that the adaptation to circadian changes is poorer in older workers, which lead to major dysregulation of the circadian system, followed by symptoms of intolerance like less sleep duration, disturbed sleep and depression (Costa & Di Milia, 2008).

On the opposite side, eight studies suggested that older age is associated with more tolerance to shift work in some of the variables measured. These results may be due to the “healthy worker effect”, which refer to a selection bias where workers with less tolerance to shift work are more likely to leave this system, while more tolerant workers remain in the workforce (Li & Sung, 1999). However, with all the evidence compiled here, and in previews reviews, showing a positive relationship between older employees and shift work tolerance, it is also necessary to explore different hypotheses. Nowadays, the dominant perspective in the literature is the physiological one that assumes and highlights that aging would be an impairment to tolerance and recovery from shift work because of normal biological deterioration. However, from a psycho-social perspective,
older workers have more experience, and often use better strategies and coping mechanisms in stressful situations compared to younger ones (Diehl, Coyle, & Labouvie-Vief, 1996). From this point of view, aging is not necessarily an impairment, but rather an improvement. It is important to highlight that from the six longitudinal studies, four of them showed that older age was associated with better tolerance (symptoms of insomnia, parasomnia, sleep time, and diabetes).

Additionally, this review found that two studies showed that middle age workers (between 38-42 years old and 42-52 years old) had poorer tolerance than older and younger employees. Similar results suggested that the higher point of intolerance to shift work is at the age between 45-50, due to biological reasons like changes in the circadian rhythm and chronotype preferences. This intolerance also could be explained as a result of psychological and social changes that occur around that age range, such as major life decisions and bigger family responsibilities that lead some people to change jobs and leave shift work (Costa & Di Milia, 2008; Reinberg, Ashkenazi, & Smolensky, 2007; Takahashi et al., 2006).

Finally, 12 articles reported that there is no significant association between age and different variables used to measure shift work tolerance. Similar results were obtained in previews reviews, where the most common outcome was a non-significant association between age and shift work (Blok & de Looze, 2011; Saksvik et al., 2011).

**Theoretical and methodological implications**

This disparity in the results of this review, and in the literature, about the effect of aging and shift work can be explained by the lack of consensus and operationalisation of shift work tolerance. The common definition refers to the lack of sleep disturbance, fatigue, and gastrointestinal issues. However, today tolerance is being measured by a wide range of other physiological and psycho-social variables. As Nachreiner (1998) previously mentioned regarding this issue, it is not possible to construct well-designed instruments for badly defined constructs. Furthermore, even when researchers referred to the same variable, usually they measured it by different methods. For example, to measure sleepiness, the study #1 used two questions on a scale, the study #19 used the Epworth sleepiness scale, and the study #23 used a modified version of the Karolinska Sleepiness Scale.
Another aspect to consider that could be influencing the results is that the research on this topic is focusing more on the individual than on the characteristics of the organisation. Job aspects and working conditions, like work demands, quality of leadership, or social support also, are usually excluded. An investigation into how these and another characteristic can add to or mitigate the interactional effects of age and shift work may show different and interesting results.

Moreover, none of the articles examined considered, or took action to, mitigate the possible effects that could have occurred when and where the participants answered the questionnaires. Respondent fatigue refers to a reduced respondent engagement to the questionnaire due to the length, content or context in which it is answered. Response fatigue can cause drops in the rate of reply, measurement error and misclassification problems (Egleston, Miller, & Meropol, 2011). This phenomenon becomes more critical in shift work settings due to usually high demands and exhaustion of employees during and after a shift. It is not the same evaluating sleepiness or fatigue before, during or after a night shift, and it is not the same assessing the same variables during a day, night or day off. This is also relevant considering the length of the questionnaires of the studies. For example, study #19 used various methods of assessment, like socio-demographic questions, the Hospital Anxiety and Depression Scale, the Bergen Insomnia Scale, Epworth Sleepiness Scale and the Fatigue Questionnaire.

In term of quality, most of the studies reviewed were cross-sectional, and the variables used to measure shift work tolerance were usually of a subjective nature, like sleep-related issues, the consequences of which are immediate or short-term. Only two studies were longitudinal, with objective measures, searching for long-term consequences of shift work (Diabetes and inflammatory response). This may represent a potential bias associated with the design adopted, owing to the fact that cross-sectional studies with subjective measures are less complicated to set up, but do not necessarily investigate major or the most significant repercussions.

Regarding the description of the sample, some of the studies have incomplete information about the age range and distribution of the participants, which made them difficult to compare with others results. Furthermore, even if the studies have full details of the sample, the categories of “old” and “young” can be completely different. This is a recurrent issue in research regarding aging; there is no fixed or conventional parameter to define what is old and young. For example, study #3 reported that older workers (>50
years) had less sleep duration than younger workers (<35 years). Meanwhile, the study #5 showed that there is no significant relationship in fatigue and health between older (28-37 years) and younger employees (20-27 years). If we consider the parameters of the study #3 to define what is old and young, all the sample of the study #5 would be categorized as young workers; therefore, their results do not have any significance because they are comparing the same age group.

**Recommendation for future research**

For future research, there are a few key points that are necessary to highlight due to the results of this study. Firstly, it is necessary to reach a consensus regarding the concept, definition and variables used to measure shift work tolerance. Secondly, there is a need to formulate a protocol to be used in cases of shift work research. Because the effect of age and shift work tolerance could be influenced by when the questionnaire was completed (day, night or day off), a guideline regarding this issue could help to obtain more consistent results within the studies and future reviews. Thirdly, it is necessary to reach an agreement in terms of when an employee is considered “old” or “young” for the purposes of research. The discrepancy that exists today in the literature in defining who is old or young could be affecting the results, and making it harder to carry out further studies. Finally, more longitudinal studies are required, addressing the previous issues, to conclude about the predictive power of aging over shift work.

**Applied implication**

Due to the different results found in this review, it is not possible to recommend the inclusion or exclusion of older workers in shift work. It is also not possible to suggest specific approaches to a particular population of employees. What is clear at the moment is that shift work has adverse effects on the physical and mental health of workers, and companies or workers themselves can make use of certain general recommendations to mitigate these problems.

It is evident that sleep related issues are the most common consequences of shift work on the employee, and it is possible that some organisations are not aware of this problem because the issues manifest themselves outside of working hours. Therefore, it is recommendable to sensitise and train about the topic. Sleep hygiene programmes are easy to implement, and are well known to show positive results. There is not an instant solution for sleep difficulties, every shift worker is different, but with information and an
extensive range of options regarding recommendations, they can find what works for them. Some basic advice is:

- Arrange the sleeping environment to feel comfortable
- Avoid disturbances by telling your family and friends that you are not going to be available during your sleep time
- Avoid light during your sleep time by installing heavy curtains, use a sleeping eye mask, and use sun glasses returning from home
- Avoid heavy noises. Soundproofing the room or a pair of earplugs are excellent options. Nowadays, it is essential to mute or turn off the mobile phone.
- Regulate the temperature of your room to be optimal for sleep (between 18°C and 23°C)
- Develop a regular bedtime habit. Go to bed and get up at the same time each day to help your mind and body to get used to this different schedule.

About the aging of the workers, there are different approaches and suggestions for a successful management of the age within the organisations, such as:

- Better and adequate recruitment and selection process directed to this age group
- Information transfer management policies between experienced and new workers
- Ensure lifelong training and career development within the organisation
- Promotion and health checks within the company
- Policies for proper retirement management

**Conclusion**

This review has revealed that there is no clear interaction between ageing and shift work because the information collected shows contradictory results in the current literature. Even though studies were found to support the notion that older workers have greater difficulty tolerating and recovering from shift work, there is also vast evidence that shows the opposite. Unable to firmly conclude on this relation, this review leaves open the question about the relation between the age and shift work.


Egleston, B. L., Miller, S. M., & Meropol, N. J. (2011). The impact of misclassification
due to survey response fatigue on estimation and identifiability of treatment effects. *Statistics in Medicine, 30*(30), 3560–3572. https://doi.org/10.1002/sim.4377


Conflict of interest

The author of this dissertation confirm that has NO affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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