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Dietary and lifestyle habits and the associated health risks in shift workers

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Abstract

Traditionally only a small proportion of the workforce was engaged in shift work. Changing economic pressures have resulted in increased engagement in shift work, with approximately 17 % of the workforce in Europe engaged in this work pattern. The present narrative review aimed to summarise the data on the effects of shift work on the diet, lifestyle and health of employees, while addressing the barriers to, and opportunities for, improving health among shift workers. Shift work can result in low-quality diet and irregular eating patterns. Adverse health behaviours are also reported; particularly increased smoking and poor sleep patterns. These altered lifestyle habits, in conjunction with disruption to circadian rhythms, can create an unfavourable metabolic phenotype which facilitates the development and progression of chronic disease. Although the data are inconclusive due to issues such as poor study design and inadequate control for confounding factors; shift workers appear to be at increased mental and physical health risk, particularly with regard to non-communicable diseases. Information is lacking on the obstacles to leading a healthier lifestyle while working shifts, and where opportunities lie for intervention and health promotion among this group. In order to provide an informed evidence base to assist shift workers in overcoming associated occupational hazards, this gap must be addressed. This review highlights the unique nutritional issues faced by shift workers, and the subsequent effect on health. In societies already burdened with increased incidence of non-communicable chronic diseases, there is a clear need for education and behaviour change interventions among this group.

Key words: Dietary habits: Lifestyle: Shift workers

Introduction

Traditionally only a small proportion of the work force was engaged in shift work. In recent times, working patterns have adapted in response to changes in economic pressures and greater consumer demand for services that operate on a '24 hour a day' basis, resulting in an increase in shift work. The term 'shift work' often covers a wide variety of working arrangements. The Council Directive 93/104/EC of 23 November 1993 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 times over a given period of days or weeks'[1,2]. However, there is no consensus definition of the term among the published scientific literature. In simple terms, shift work is often referred to as working primarily outside of normal daytime working hours or on a schedule other than the standard working week. Shift patterns vary depending on the timing of the shift (early morning, afternoon, evening, night), the rotation cycle (number of days between two identical sequences), the direction of rotation (forward or backward rotating) and the stability of the time slots planned (permanent shifts *v.* rotating shifts)[3]. In Europe approximately 17 % of the workforce is engaged in this type of work schedule[4].

There are many economic advantages to an increase in shift work, namely the creation of employment, increased provision of services to customers and improved trade opportunities. Unfortunately, shift work has been reported to have a negative impact on the health of workers and is accompanied by greater incidence of non-communicable diseases such as cancer[5], CVD[6], metabolic[7], gastrointestinal[8] and sleep disorders[9]. Many of the risk factors for non-communicable diseases, including poor diet, lack of physical activity, deleterious lifestyle behaviours such as excess alcohol and smoking, insufficient sleep and being overweight, are frequently reported among shift workers. The aim of the present review is to evaluate the current status of the evidence on the diet and lifestyle habits of shift workers, and the subsequent health risk compared with non-shift workers. In addition, the evidence for barriers and opportunities for improving the health and lifestyle of this group will also be explored, which extends the scope of previous reviews in this area.

Abbreviations: IDF, International Diabetes Federation; MetS, metabolic syndrome; NCEP ATP-III, National Cholesterol Education Program Adult Treatment Panel III; T2DM, type 2 diabetes mellitus.

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Methodology

This is a narrative review which aimed to summarise the effects of shift work on workers' lifestyle and health risk, and to address the barriers to and opportunities for shift workers to lead a healthier lifestyle. An extensive literature search for relevant peer-reviewed scientific articles and reports was conducted, using targeted Internet searches, for example, Medline and Web of Knowledge. Key words searches were conducted using the terms 'shiftwork' or 'shift work'. Articles were considered if they were available in full text, were in English and were conducted among human subjects. The relevance and strength of each article are dealt with throughout the text, with critical comments on the factors which made for higher- and lower-quality publications.

Shift work and lifestyle habits

Dietary intakes

Table 1 summarises the results of studies investigating dietary intakes among shift workers. Earlier studies in the area showed that, overall, total energy intake of shift workers is similar to that of day workers[10–14], with this being confirmed by more recent findings[15–19]. However, methodological issues existed in many of these studies, with small sample sizes[10,18,20], reliance on self-reported food diaries[11,18–20] and failure to compare dietary intakes with non-shift worker controls[16,18] apparent. Due to these limitations in study design and to variability in defining shift work and assessing dietary intake, results between studies are difficult to compare.

While total energy intake does not appear to be affected, shift work may make an impact on diet quality. Alterations in macronutrient intakes have been observed, such as increased intake of saturated fat[14,19] and decreased intake of polyunsaturated fat[21] and dietary fibre after commencing shift work[20]. In addition, decreased intake of a number of essential micronutrients, such as vitamins A, D and E, and Zn is documented among shift workers, relative to day workers[21]. Furthermore, one study reported that the diets of shift workers, and in particular rotating shift workers, were significantly more pro-inflammatory than day workers[22], but the biological significance of this in terms of dietary inflammatory load remains unclear. Along with alterations in dietary quality, much of the recent evidence has collectively shown that shift workers differ from day workers with respect to the distribution of their energy intake over 24 h[10,15,16,18,19]. Erratic meal patterns, increased consumption of energy later in the day and increased snacking were common, with multiple snacks being consumed during the night shift in place of a full meal. The significance of these altered dietary habits must be considered. There is convincing evidence that night time eating can cause disruptions to endogenous circadian rhythms, compared with day time eating[18,23–27], which can result in significantly elevated postprandial TAG levels and plasma glucose levels on the night shift, as compared with the day shift. This may have negative implications for health, particularly in relation to risk of insulin resistance, type 2 diabetes mellitus (T2DM) and the metabolic syndrome (MetS). It has therefore been suggested that restricting fat intake at night time in workers who are not adapted to night shift work may be beneficial[26].

Physical activity

The evidence of the impact of shift work on physical activity presents a mixed picture (Table 2). Studies have reported negative[28,29], positive[19,30,31] or no effects[32,33] on levels of physical activity in shift workers compared with day workers. However, the definitions of physical activity used may, at least in part, contribute to these equivocal results. Different measures used include leisure-time activity, habitual activity, total activity and/or occupational activity. Even when studies have analysed both occupational and leisure-related activity, differences in results have been observed. Some have reported that shift workers had significantly higher occupational activity compared with day workers, resulting in significantly higher overall total activity[19,34], while others have reported that shift workers had lower occupational activity but higher leisure-related activity[35]. One factor potentially contributing to these inconclusive results is the occupational heterogeneity of subjects in these studies. Broadly speaking, subjects were recruited from manufacturing[19,29,30,32], transport[30,31,35], security[30,36] or healthcare[33,34] sectors, with roles potentially varying widely in terms of occupational activity. Another limitation is that much of the evidence is cross-sectional in nature and relied on self-reported data, with just one study[31] using actigraphy to compare activity levels between day workers and shift workers. Objective measures such as this would provide more reliable data. Unfortunately, despite the number of studies in this area, the discrepancies in study design mean that no definitive conclusions can be currently drawn on the effects of shift work on physical activity.

Despite the lack of conclusive evidence, barriers to engagement in regular physical activity among this group have been explored. Shift workers may have difficulty in implementing and maintaining an active lifestyle[37], with reasons such as fatigue due to a demanding schedule, difficulty engaging in social forms of exercise or team sports, possible increased perceived exertion and fatigue during exercise performed at night or in the early morning[38] all cited. A lack of facilities available at times convenient to shift workers may also be an issue. The health implications of an inactive lifestyle are large, with indisputable evidence for the effectiveness of regular exercise in the prevention of chronic non-communicable diseases and premature death[39]. Where it occurs, physical inactivity therefore may exacerbate the risk of chronic disease among shift workers.

Smoking

The results of cross-sectional data and cohort studies exploring smoking habits among shift workers are presented in Table 3. Engaging in shift work[40,41] and, in particular, night shift work[42,43] was shown to be associated with a higher prevalence of smoking[41–43] or increased number of cigarettes smoked per person[40]. Longer working hours appear to affect rates of smoking also, with working shifts >8 h in length[42] or working 49–60 h per week[41] associated with higher rates of

Table 1. Summary of studies on dietary intake in shift workers (SWs)*

Study	Sex	Sample	Study duration	Type of SW	Assessment method	Outcomes	Comment
Cohort studies							
Reinberg *et al.* (1979)[10]	Male	7 (including 5 shift workers)	8 weeks	Mixed	Food diary	TE, macroN, MF, meal timing	No difference in TE, increased snacking on night shift
Attia *et al.* (1985)[11]	Male	49 (including 39 shift workers)	15–21 d	Mixed	Food diary, 24 h recall	TE, macroN, MF, meal timing	Reduced appetite on night shift
Knutson *et al.* (1990)[20]	Male	25 (including 12 shift workers)	4 d	Mixed	Food diary	TE, macroN, vitamins, minerals	Decreased dietary fibre on night shift
Linseisen & Wolfram (1994)[21]	Male	49 (including 24 shift workers)	7 d	Night	Weighed intake	TE, macroN, meal timing, vitamins, minerals	Decreased intake of vitamins A and D, Zn, fibre
Lennernas *et al.* (1995)[15]	Male	96 (including 59 shift workers)	Length of a work cycle, including all types of work-days and days off	Mixed	Interviewer assisted 24 h recall	TE, macroN, vitamins, minerals, meal timing	Decreased EI on night shift
Pasqua & Moreno (2004)[18]	Male	28 shift workers	3 d	Mixed	Food diary	TE, macroN, MF, meal timing	Increased EI in winter
Study	**Sex**	**Controls**	**Cases**	**Type of SW**	**Assessment method**	**Outcomes**	**Comment**
Case–control studies							
Cervinka *et al.* (1984)[12]	Male	28	14	Mixed	Food diary (7 d)	TE, MF, meal timing	Increased EI on night shift
Romon-Rousseaux *et al.* (1987)	Male	74	20	Mixed	Food diary (4 d)	TE, macroN, MF, meal timing	No difference in TE on night SW
Nikolova *et al.* (1990)[14]	Male	98	17	Night	Questionnaire (3 d)	TE, macroN	Increased intake of animal fat on night shift
Waterhouse *et al.* (2003)[17]	12 % male and 88 % female	43	50	Night	Self-designed questionnaire, completed every 3 h for 7 d	MF, meal timing	Decreased appetite and MF on night shift
Study	**Sex**	**Sample size**	**Population**	**Type of SW**	**Assessment method**	**Outcomes**	**Comment**
Cross-sectional studies							
de Assis *et al.* (2003)[16]	Male	66	Garbage collectors (Brazil)	Morning, afternoon, night	24 h recall × 1, 24 h food record × 2	TE, macroN, MF, meal timing	Impact of SW was relatively less decisive than well-established determinants of human food intake behavior, for example, time of day, time elapsed since last meal, age and BMI
Morikawa *et al.* (2008)[143]	Male	2254	Japan	Rotating	Self-administered diet history questionnaire[144]	TE, macroN, vitamins, minerals	Older age and night SW associated with increased EI
Esquirol *et al.* (2009)[19]	Male	198	France	Rotating	Food diary (4 d)	TE, MF	Increased MF on night SW
Wirth *et al.* (2014)[22]	53 % male and 47 % female	7643	USA	Mixed	24 h recall, 7 d recall	MacroN, microN, dietary inflammatory index	Significantly more pro-inflammatory diet in SWs, especially rotating SW

SW, shift work; TE, total energy; macroN, macronutrients; MF, meal frequency; EI, energy intake; microN, micronutrients.
* Table adapted from Lowden *et al.*[137].

Table 2. Summary of studies on physical activity (PA) in shift workers (SWs)

Study	Sex	SWs (*n*)	Controls (*n*)	Population	Type of SW	Assessment method	Outcomes	Comment
Cross-sectional studies								
Nagaya *et al.* (2002)[30]	Male	826	2824	Japan (transport/security/ manufacturing)	Mixed	Self-administered lifestyle questionnaire, medical examination	IR markers, PA, BMI, smoking, alcohol	SWs have more habitual PA than day workers
Karlsson *et al.* (2003)[32]	Male	659	665	Sweden (manufacturing plant workers)	Rotating	Health and lifestyle questionnaire, medical examination	Anthropometry, PA, BP, fasting blood glucose, fasting lipid profile	No difference in PA between SWs and day workers
Esquirol *et al.* (2009)[19]	Male	100	98	France (chemical plant workers)	Mixed	Validated questionnaire[145]	Anthropometry, PA, dietary habits	SWs have more occupational PA than day workers and significantly higher overall total PA
Bushnell *et al.* (2010)[29]	69 % male and 31 % female	12 725	13 717	Mixed (chemical manufacturing workers)	Mixed	Online survey	Health behaviours, physical health, work environment	Significantly higher prevalence of no PA for rotating workers and shifts of 12 h
Diaz-Sampedro *et al.* (2010)[33]	N/A	311	0	Spain (healthcare workers)	Mixed	Self-designed questionnaire	Food consumption, BMI, PA	SW did not have a negative impact on PA
Ma *et al.* (2011)[36]	71 % male and 29 % female	350	0	USA (police officers)	Day, afternoon, night (fixed schedules)	7 d physical activity recall questionnaire[146]	Work details, PA, alcohol intake, smoking, BMI, WC	SW associated with prevalence of hard-intensity occupational and sport PA among male officers, and very hard-intensity sport PA among female officers. Afternoon SWs reporting highest prevalence of PA
Barbadoro *et al.* (2013)[35]	Male	110	229	Italy (railway service employees)	Rotating	Self-administered questionnaire	Food consumption, PA, alcohol intake, BMI, personal and family history of obesity	Rotating SWs less active in workplace ($P<0.001$) but significantly more active during leisure time ($P<0.05$), compared with day workers
Marqueze *et al.* (2014)[31]	Male	31	26	Brazil (truck drivers)	Night	IPAQ[147], actigraphy	PA, BMI, appetite-related hormones	SWs significantly more active in leisure time *v.* day workers. PA < recommended 150 min/week in both groups
Peplonska *et al.* (2014)[34]	Female	354	371	Poland (nurses and midwives)	Rotating	IPAQ[147]. Analysis adjusted for age, season of the year, number of full-term births, marital status and BMI	PA, BMI	Total and occupational PA significantly higher among for rotating SW *v.* day work. Leisure-time PA significantly affected by rotating SW with increased OR for recreational inactivity (OR 1·57; 95 % CI 1·11, 2·20)

SW, shift work; IR, insulin resistance; BP, blood pressure; N/A, not available; WC, waist circumference; IPAQ, International Physical Activity Questionnaire.

Table 3. Summary of studies on smoking in shift workers (SWs)

Study	Sex	Sample	Study duration	Number of follow-up events	Type of SW	Exposure	Outcomes	Comment
Cohort studies								
van Amelsvoort *et al.* (2004)[40]	49 % male and 51 % female	377 (of which 227 SWs) Netherlands	1 year	Validated questionnaires[145,148] at beginning of new work schedule and 1 year after	Rotating (detailed coding)	Work schedule, smoking history	CVD risk factors, current smoking	Significantly more SWs were current/former smokers at baseline ($P=0.006$). At follow-up the number of cigarettes smoked per d by smokers increased more in SWs compared with day workers ($P=0.03$)
van Amelsvoort *et al.* (2006)[44]	73 % male and 27 % female	7819 (of which 2039 SWs) Netherlands	2 years	Follow-up every 4 months, questionnaire	Rotating	Work schedule, smoking history, work-related factors, for example, psychological job demands, decision latitudes	Smoking – prevalence and cessation/ commencement	SWs were more often smokers (OR 1·44; 95 % CI 1·27, 1·64) and more likely to start smoking compared with day workers (OR 1·46; 95 % CI 1·05, 2·03)
Nabe-Nielsen *et al.* (2008)[43]	5 % male and 95 % female	2870 (social and health care assistants, of which 1387 SWs) Denmark	1 year	Questionnaire at baseline when commencing work, and 1-year follow-up	Night/rotating	Usual work schedule, smoking history, presence of CVD risk factors	Presence of CVD risk factors at baseline (including smoking) and reported work pattern at 1-year follow-up	Smoking status at baseline associated with shift work at follow-up for fixed evening work (OR 1·56; 95 % CI 1·23, 1·98), fixed night work (OR 1·72; 95 % CI 1·12, 2·63), and two- or three-shift work (OR 1·36; 95 % CI 1·01, 1·82). Suggests considering smoking as a confounder between SW and CVD, as well as a mediator
Nabe-Neilsen *et al.* (2011)[46]	Female	2062 (social and health care assistants) Denmark	2 years	Baseline, 1-year and 2-year follow-up	Evening/night/ rotating	Work patterns at each time point, smoking history	Smoking prevalence at each time point	Fixed night work was associated with higher odds of smoking relapse (OR 5·28; 95 % CI 1·47, 18·9; $P=0.057$) and lower odds of smoking cessation (OR 0·11; 95 % CI 0·02, 0·79; $P=0.007$)
Study	**Sex**	**Sample size**	**Population**		**Type of SW**	**Assessment method**	**Outcomes**	**Comment**
Cross-sectional studies								
Trinkoff & Storr (1998)[42]	5 % male and 95 % female	3917	Registered nurses (USA)		Mixed	Self-designed questionnaire × 3	Past-year drug/alcohol/ cigarette use, work schedule	As compared with day workers, greatest risk of smoking associated with night SW (OR 1·59; 95 % CI 1·23, 2·07; $P<0.01$) and evening SW (OR 1·27; 95 % CI 0·94, 1·73; NS). Rotating SW NS risk (OR 1·02; 95 % CI 0·77, 1·35)
Janzon *et al.* (2005)[45]	Female	17 319	Malmo Diet and Cancer Study (Sweden)		Any	Self-designed questionnaire	Lifestyle habits, medical history	SWs less likely to quit smoking than day workers, SW identified as a social factor likely to hinder smoking cessation
Cho *et al.* (2013)[41]	53 % male and 47 % female	4685	Fifth Korean National Health and Nutrition Examination Survey (South Korea)		Night	Health surveys, examinations, nutrition surveys – administered by trained interviewers	Work schedule and type, smoking (classification of night SWs could have been more robust)	Work conditions associated with smoking behaviour for women only. Adjusted OR for night SW exposure and smoking: men (OR 1·11; 95 % CI 0·82, 1·49); women (OR 1·38; 95 % CI 0·83, 2·29)

SW, shift work.

smoking. Shift workers have also been shown to be more likely to take up smoking once engaged in shift work[44]. Furthermore, it has been reported that shift workers are less likely to quit smoking[45,46] and have higher odds of smoking relapse[46] compared with day workers.

Alcohol

The results of observational studies of alcohol consumption among shift workers are presented in Table 4, with mixed reports observed. Shift workers may use alcohol in an attempt to overcome difficulties sleeping[47], or to ease the stresses associated with their work pattern[29]. In the included studies, 'heavy drinking' was typically defined as >40–60 g of alcohol per d[48–50], ≥5 drinks on one occasion[42], or increased consumption on previous measurements of consumption[51]. A modestly increased risk of heavy drinking was associated with shift work by some, and this was typically related to younger age[50], night shift[42,49] or rotating shift[29,42] of greater than 8 h in length. However, in some cases, this relationship was mediated by shift work-related sleep issues[49]. In contrast, other studies have found no association[48] or an inverse association[51,52] between shift work and alcohol consumption. As shift work often interferes with family time and social activities, there may be reduced opportunities for social alcohol consumption among this group. In summary, while shift work may increase the likelihood of increased alcohol consumption, available data are merely observational in nature and various factors such as age, sex and shift type or length may potentially influence this.

Sleep patterns

Shift workers report more sleep problems compared with the general public, and it has been estimated that 10–30 % of shift workers suffer from shift work disorder[53], a circadian rhythm sleep disorder characterised by insomnia and excessive sleepiness[54]. Some of the most problematic symptoms reported are difficulty falling asleep, shortened sleep duration and somnolence during working hours that persists during days off[55]. Levels of sleep disturbance have been compared with clinical insomnia[56].

Shift patterns, shift lengths, direction of rotation, and length of recovery time between shifts have been examined, with respect to their impact on sleep patterns. Those working night shifts, rotating night shifts and early morning shifts have been reported to have the shortest average sleep duration or the most disturbances in sleep–wake patterns[55–58]. Forward rotating shift schedules are considered to be more beneficial to workers in terms of health and sleep disturbances, along with moving from slow- to fast-rotating shifts[59–61]. Elsewhere, others have suggested that a slowly rotating shift pattern had the least negative impact on sleep length for schedules that include a night shift[58]. The effect of shift duration has also been investigated, with little difference noted in the effect of 8 h *v.* 12 h shifts on sleep patterns[61,62].

A lack of controlled intervention studies in the area makes it difficult to determine the true impact of different shift schedules on sleep patterns. In addition, there is evidence to suggest that there is high inter-individual variability in the ability of workers to tolerate disruption to circadian rhythm caused by shift work, adding further difficulty to the interpretation of the studies published[63,64]. Despite this, the evidence indicates that both good physical fitness and sleep hygiene (i.e. habits and practices that are conducive to sleeping well on a regular basis) can be effective in improving tolerance to shift work, by increasing overall efficiency and reducing fatigue. In terms of health risk, disrupted sleep patterns may have metabolic effects that predispose to weight gain. Short sleep duration is generally defined as ≤5–6 h sleep per 24 h, and has been associated with increased BMI[65–69]. While addressing the area of sleep duration and BMI is beyond the scope of this review, short sleep duration may potentially mediate a relationship between shift work and obesity.

Summary on the effects of shift work on lifestyle habits

Although not inevitable, shift work can result in altered lifestyle habits. Dietary habits appear to be affected, with more frequent eating occasions, poorer-quality diets and irregular distribution of energy intake over the course of 24 h. It is unclear whether shift work has an impact on physical activity patterns, with mixed results reported. Mixed reports are also observed for alcohol consumption with various factors such as age, sex and shift type affecting study conclusions. In addition increased rates of smoking are reported, with shift workers also less likely to quit smoking compared with day workers, while poor quality and quantity of sleep are also described in the literature. Socio-economic status is known to have a negative impact on dietary and lifestyle habits and on health risk[70]. However, the current review found no evidence to indicate that a social class gradient exists among shift worker groups which might influence health behaviours or health risk, or account in part for some of the differences observed in dietary and lifestyle behaviours. What is clear, however, is that the lifestyle habits described, in conjunction with disruption to circadian rhythms, may create a metabolic environment which can facilitate the development and progression of chronic disease.

Shift work and health risks

As the body has a roughly 24 h circadian rhythm, we are programmed to eat during the day and to sleep at night. The circadian system also regulates the timing of daily variations in numerous behavioural, endocrine and neurophysiological processes[71], for example, sleep–wake cycles, body temperature, blood pressure and the release of hormones. This 24 h rhythm is generated by the suprachiasmatic nucleus, which is located in the anterior hypothalamus of the brain[72]. Almost all body functions, from those at cellular level to large physiological systems, have a circadian rhythm, and thus disruptions to these rhythms have systemic implications throughout the body. The physiological effects of both circadian rhythm disruption, and the behavioural and psychological effects of shift work exposure may interact, with potential consequences for disease risk as summarised in Fig. 1.

Table 4. Summary of studies on alcohol consumption in shift workers (SWs)

Study	Sex	Sample	Study duration	Follow-up events	Type of SW	Exposure	Outcomes	Comment
Cohort studies								
Shields (1999)[51]	57 % male and 43 % female	7203 (1356 SWs)	2 years	Baseline and 2 years follow-up	Mixed	Working hours	Health behaviours	Male SWs had significantly lower odds of reporting increased alcohol intake over the 2-year period (OR 0·7; 95 % CI 0·5, 1·0; $P \leq 0·05$)

Study	Sex	Sample size	Population	Type of SW	Assessment method	Outcomes	Comment
Cross-sectional studies							
Romon *et al.* (1992)[52]	N/A	146 (73 SWs)	Chemical and nuclear plant workers (France)	Mixed	3 d food record	Dietary and alcohol intake, smoking, BMI, lipid profile	SWs had significantly lower alcohol intake than day workers (9·3 *v.* 15·64 g/d; $P = 0·03$)
Trinkoff & Storr (1998)[42]	5 % male and 95 % female	3917 (no controls)	Registered nurses (USA)	Mixed	Self-designed questionnaire x3	Past-year drug/alcohol/ cigarette use, work schedule	Those working night SW >8 h or rotating SW >8 h had highest risk of alcohol use (OR 1·40; 95 % CI 1·00, 1·98; $P = 0·05$) and (OR 1·52; 95 % CI 1·04, 2·22; $P < 0·05$) respectively
Hiro *et al.* (2007)[48]	Male	17 501 (3691 SWs)	Factory workers (Japan)	Unspecified	Self-developed questionnaire	Job stressors, recent drinking history	No association between SW and heavy alcohol consumption, increased drinking more likely to be associated with on-the-job stressors
Bushnell *et al.* (2010)[29]	69 % male and 31 % female	26 442 (12 725 SWs)	Workers from various industries	Mixed	Online survey	Health behaviours, physical health, work environment	Higher alcohol consumption among 12 h rotating shift (RR 1·22; 95 % CI 1·11, 1·33)
Morikawa *et al.* (2013)[49]	Male	909 (362 SWs)	Factory workers (Japan)	Rotating	Validated questionnaire[144]	Daily alcohol intake, sleep problems, lifestyle habits	Night SWs who suffered poor sleep quality exhibited highest frequency of heavy drinking (OR 2·17; 95 % CI 1·20, 3·93) compared with day workers with good sleep
Morikawa *et al.* (2014)[50]	Male	3398 (844 SWs)	Factory workers (Japan)	Mixed	Two validated questionnaires[144], 1 year apart	Work-related factors, job stressors, health-related behaviours, alcohol intake	SW associated with increased risk of heavy drinking in group aged 20–29 years (OR 4·79; 95 % CI 1·49, 15·44; $P < 0·01$)

SW, shift work; N/A, not available; RR, relative risk.

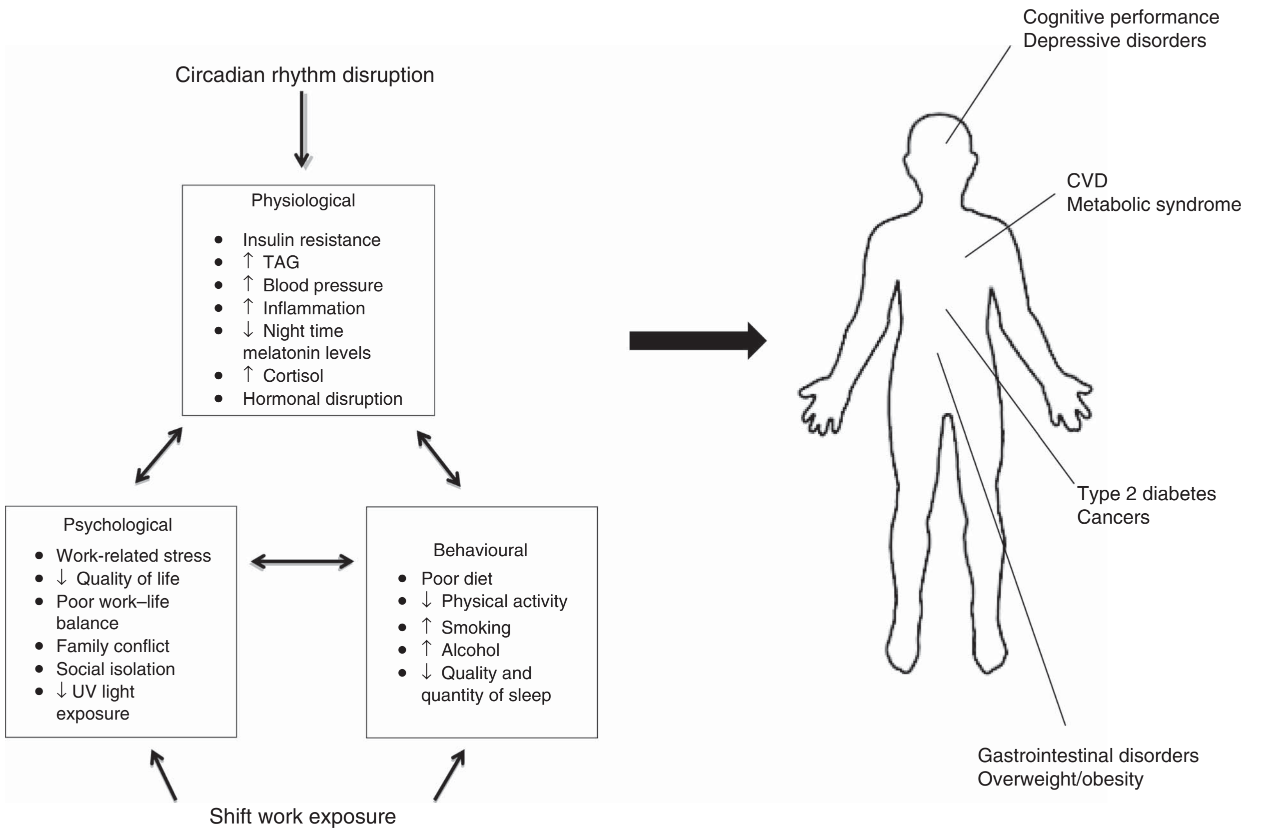

Fig. 1. Circadian disruption and shift work exposure – the potential pathways to disease.

Cancer

A 2007 report by the International Agency for Research on Cancer[5] classified shift work that involves disruption of the circadian rhythm as a probable human carcinogen. The hypothesis for a potential causal link is based on experimental evidence that melatonin, which is highest at night time, is protective against cancer development, and that exposure to night shift work reduces melatonin levels via increased exposure to light at night. Although extensive observational and cross-sectional data have been published on the relationship between shift work and cancer, inclusion of these studies is beyond the scope of the present review. However, a number of systematic reviews and meta-analyses based on observational data have been conducted, and are summarised in Table 5.

A large proportion of the research into shift work and cancer risk has specifically addressed breast cancer, mainly owing to early interest in breast cancer risk among nurses and flight attendants. Many of these early observational studies showed weak to moderate evidence for an association between breast cancer and shift work; however, these studies had their limitations. Several of the systematic reviews and meta-analyses have since reported moderately increased breast cancer risk due to shift work[73,74] and a positive dose–response relationship between shift work exposure and incidence of breast cancer[75]. Others have, however, reported limited evidence to support the association between the two[76] and have highlighted study limitations such as immeasurable confounding and substantial between study heterogeneity as issues in their analyses. Nonetheless, only one of the systematic reviews/meta-analyses reported insufficient evidence for a causal link[77], citing the low quality of the exposure data as problematic in providing conclusive evidence. Currently we can only state that while there appears to be some associated increased risk of breast cancer for those engaging in shift work, further work is required to reach a consensus.

Evidence for an association between other forms of cancer and shift work is not particularly strong, with weak or conflicting data reported. This may be, at least in part, owing to a lack of high-quality research in this area. Both the risk of individual cancer types and overall cancer risk have been assessed among shift workers. Those studies addressing all-site cancer risk found insufficient evidence for increased risk among shift workers[76,78]. The association between shift work and colon cancer and colorectal cancer has been explored. With regard to the risk of colorectal cancer among shift workers, reports from the Nurses' Health Study showed an increased risk of colorectal cancer among those with long-term exposure (≥15 years) to shift work[79]; however, elsewhere a critical review found there was insufficient evidence to support an association between shift work and risk of colon cancer, due to the low number of studies in the area[76]. Prostate cancer risk has also been investigated among this group. Again, as with studies on other cancer types, conflicting results are reported, with insufficient evidence to support an

Table 5. Summary of studies on cancer risk in shift workers

Study	Study type	Sex	Type of SW	Cancer site	Exposure	Outcomes	Confounders controlled for*	Comment
Systematic reviews and meta-analyses								
Megdal *et al.* (2005)[73]	SR/MA	Female	Night	Breast	Any overnight work	Histologically confirmed breast cancer	Age, social class, age at menarche, parity, age at first birth, BMI, family history of breast cancer, benign breast disease, OC use, age at menopause, alcohol consumption, HRT use, menopausal status, height, employment duration	Increased risk; aggregate risk estimate for all studies 1·48 (95 % CI 1·36, 1·61) compared with no exposure
Kolstad (2008)[76]	SR	Male and female	Rotating, night	Breast, prostate, colon	Years of night SW (eleven studies), rotating shift (two studies)	Cancer diagnosis confirmed by: national/regional cancer register, medical records, death certificates	Age, SES, age at menarche, parity, age at first birth and last birth, BMI, family history, benign breast disease, OC use, alcohol, smoking, PA, diet, aspirin use, stress, calendar year, age at menopause, HRT use, menopausal status, height, duration of employment, current job title	Limited evidence for association with breast cancer, insufficient evidence for prostate, colon and overall cancers
Sigurdardottir *et al.* (2012)[80]	SR	Male	Rotating, night	Prostate	Proxies of circadian disruption (light at night, sleep duration, occupations likely to include night SW)	Prostate cancer incidence/mortality	Age, ethnicity, SES, marital status, education, job status, income level, urbanisation, region, history of disease, family history of cancer, BMI, smoking, alcohol consumption, calendar periods	Suggestive evidence, to be interpreted with caution as some studies used occupation as a proxy measure of SW
Wang *et al.* (2013)[75]	MA	Female	Night	Breast	Night SW exposure (measured by employment years, cumulative exposure and frequency of exposure)	Breast cancer incidence	Age, education, age at menarche, menstrual regularity, parity, age at first birth, weight change between age 18 years and menopause, BMI, height, family history of breast cancer, benign breast disease, number of mammograms, OC use, current alcohol consumption, smoking, PA, menopausal status, age at menopause, HRT use, employment duration	Positive dose–response relationship, pooled RR 1·03 (95 % CI 1·01, 1·05; $P<0·001$)
Kamdar *et al.* (2013)[74]	SR/MA	Female	Night	Breast	Night SW exposure (ever, short-term, long-term)	Breast cancer incidence	Age, SES, education, age at first childbirth, menarche, parity, live births, menopausal status, OC use, HRT use, height, BMI, age 18 years to menopause weight difference, family history breast cancer, benign breast disease, breast-feeding, mammograms, alcohol, smoking, PA, year of diagnosis, occupational position, employment duration	Weak evidence, pooled RR for ever having night shift exposure 1·21 (95 % CI 1·00, 1·47; $P=0·056$) compared with never exposed
Ijaz *et al.* (2013)[77]	SR/MA	Female	Night	Breast	Night SW exposure (shift system, years duration of exposure, frequency of exposure)	Breast cancer incidence (confirmed by histopathology in ≥90 % of cases)	Age, BMI, ethnicity, parity, SES	Insufficient evidence, low quality of exposure data and difference in effect by study design

Table 5 *Continued*

Study	Sex	Population	Sample size	Type of SW	Cancer site	Exposure	Outcomes	Comment
Cohort studies								
Schernhammer *et al.* (2003)[79]	Female	USA	78 586	Rotating, night	Colorectal	SW exposure defined as number of years spent working ≥3 rotating night shifts per month	Cancer incidence (medical records, national death index)	Rotating night shift for ≥15 years has RR of 1·35 (95 % CI 1·03, 1·77) compared with no exposure
Schwartzbaum *et al.* (2007)[78]	65 % male, 35 % female	Sweden	3 250 787 (of which 72 816 shift workers)	Rotating, night	All sites	SW exposure obtained from census data at two time points (1960, 1970)	Swedish Cause of Death Register, Swedish Cancer Register	Men: SIR 1·02 (95 % CI 1·00, 1·05). Women: SIR 1·00 (95 % CI 0·89, 1·13). No evidence for association between SW and all cancer sites combined

SW, shift work; SR, systematic review; MA, meta-analysis; OC, oral contraceptive; HRT, hormone replacement therapy; SES, socio-economic status; PA, physical activity; RR, relative risk; SIR, standardised incidence ratio.
* For systematic reviews/meta-analyses all confounders controlled for are included. All may not be included in each individual original study.

association in one study[76], and another reporting suggestive evidence for an association[80]. Overall, evidence for an effect of shift work on cancer risk appears inconclusive, with much variability in study methodologies, including the methods to define shift work and shift work exposure, and the control for confounding factors frequently unclear.

Obesity

Obesity has been identified as another health risk associated with shift work. Studies in the area are presented in Table 6. Epidemiological data suggest that shift workers appear to be heavier, or gain weight more often than day workers[81–85]. It has also been demonstrated that obesity risk increases according to the duration of shift work exposure[83,86,87]. Studies which reported on the longitudinal trends in BMI and shift worker status found that maintaining or changing shift work status can make an impact on BMI[82,84]. Those who maintained shift work patterns, or who changed from regular daytime hours to shift work, had a significant increase in BMI. These associations remained after adjusting for confounding variables. While BMI is a useful tool in estimating body fat, waist circumference and waist:hip ratio are useful for estimating central adiposity which is associated with increased health risk. Studies assessing central adiposity revealed a significant association between shift work and increased waist:hip ratio[85,86], yet these studies revealed no significant associations between BMI and shift work. This suggests that while shift work may not necessarily increase overall body weight it may detrimentally influence body fat distribution with a tendency towards central adiposity, which may have potential implications for the metabolic and cardiovascular health of shift workers.

As with other studies in this area, the methodological problems noted previously apply in many of these studies. One systematic review found strong evidence for a crude relationship between shift work exposure and weight gain; however, this evidence was considered insufficient once adjustments for confounding factors were made[88]. Another review article on obesity and shift work showed that while there was considerable epidemiological evidence that shift work was associated with an increased risk of metabolic disturbances, such as obesity, many articles included in the review were potentially biased due to lack of protocols to control for confounding factors when anthropometric measures such as height and weight were self-reported[89]. While the majority of these studies showed a tendency towards a positive association between shift work and being overweight or obese, the methodological issues recognised highlight that future studies need to address these in order to identify the true impact of shift work on body weight.

Metabolic syndrome

Circadian rhythm disruption can create metabolic disturbances such as lipid and glucose intolerances, with levels shown to be significantly elevated throughout the night shift compared with the day shift[26]. This may potentially contribute towards the risk of the MetS among shift workers. The results of studies addressing shift work and the MetS are presented in Table 7.

Nutrition Research Reviews

Table 6. Summary of studies on obesity risk in shift workers

Study	Study type	Sex	Articles included	Type of SW	Exposure	Outcomes	Confounders controlled for*	Comment
Systematic reviews								
van Drongelen *et al.* (2011)[88]	SR	Male and female	8	Night SW	Large differences between studies for SW exposure, population, sample size, duration of follow-up. Hence no overall MA performed	Body weight, BMI, WHR (two studies relied on self-reported measures)	Age, sex, BMI at baseline, alcohol consumption, smoking, PA, births during study period, duration of SW, decision authority, psychological demands, communication with colleagues, conflicts at work, job insecurity	Strong evidence for crude relationship between SW which includes night work, and body-weight gain. Evidence for a confounders-adjusted relationship between SW exposure and body weight was considered insufficient

Study	Sex	Sample	Study duration	Follow-up events	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Cohort studies									
Morikawa *et al.* (2007)[82]	Male	1529 (blue collar factory workers)	10 years (1993–2003)	Baseline and 10 year follow-up	Rotating	Work schedule (categorised according to changes and non-changes over 10 years)	BMI, BP, HbA1c, serum cholesterol, dietary intake	Age, smoking, alcohol consumption, PA	Suggestive evidence that SW related to weight gain. Over 10-year period, transferring from fixed daytime to SW ($P = 0.04$) or maintaining SW ($P = 0.019$), is significantly associated with increased BMI. Association remains after adjusting for confounding factors (for example, age, smoking, alcohol, PA)
Zhao *et al.* (2012)[84]	Female	2078 (nurses and midwives)	2 years	Baseline and 2-year follow-up	Mixed	Work schedule (categorised according to changes and non-changes over 2 years)	BMI	Diet quality, smoking, alcohol consumption, PA, mental health status, menopausal status	Significant increase in BMI over 2 years for those who moved from day work to SW (+0·13 BMI units; $P = 0.04$) or maintained SW (+0·56 BMI units; $P = 0.01$). Those who moved from SW to day work had a significant reduction in BMI (–3·02 BMI units; $P < 0.001$). Significance remained after adjusting for confounding factors

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Table 6 *Continued*

Study	Controls	Cases	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Case–control studies							
van Amelsvoort *et al.* (1999)[83]	152 (daytime workers)	225 (nurses, waste incinerator plant workers)	Mixed	Duration of SW calculated via assessment of current and past job titles, SW schedules, and start and end dates of each	Weight, height, WC, hip circumference	Age, smoking, PA, education level, last SW exposure >1 year ago	Suggestive evidence of relationship between years in SW with BMI and WHR. Linear regression coefficients were 0·12 kg/m^2 per year in SW for BMI ($P<0·05$), and 0·0016 per year in SW for WHR ($P<0·05$)
Parkes (2002)[87]	787 (offshore personnel, day shift workers)	787 (offshore personnel, day–night shift workers)	Rotating, night	SW exposure recorded in years. Day–night workers and permanent night workers classified as cases	Anthropometry	Age, education level, smoking, job type	NS difference in BMI between cases and controls when adjusted for age. For cases BMI predicted by years of SW exposure (r 0·19; $P<0·025$)
Di Lorenzo *et al.* (2003)[81]	134 (chemical industry workers, day shift 07.00–16.00 hours)	185 (chemical industry workers, three shift rotating)	Rotating	Working age (minimum 5 years), shift type	BMI, WC, WHR	BP, TAG, HDL-cholesterol, insulin, fasting blood glucose	Obesity significantly higher among rotating SW *v.* day workers ($P<0·05$), body fat distribution NS different between groups. Association independent of age and work duration

Study	Sex	Sample size	Population	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Cross-sectional studies								
Nakamura *et al.* (1997)[85]	Male	299	Japan (industrial blue collar workers)	Rotating two-shift, rotating three-shift	Work schedule	Weight, height, WHR, skinfold thickness, lipid profile, BP	Age, PA, alcohol, smoking, snacking habits	Suggestive evidence. WHR were 0·905 (SD 0·060) for three-shift workers and 0·877 (SD 0·054) for day workers ($P<0·05$)
Ha & Park (2005)[86]	37 % male and 63 % female	360	Korea (female nurses, male blue collar workers)	Rotating	Lifetime occupational history focusing on SW experience and duration	BMI, WHR, BP, blood glucose, cholesterol	Job stress, alcohol consumption, smoking, PA	BMI not significantly associated with SW. WHR significantly associated with SW duration in females >30 years. No comparison with controls

SW, shift work; SR, systematic review; MA, meta-analysis; WHR, waist:hip ratio; PA, physical activity; BP, blood pressure; HbA1c, glycosylated Hb; WC, waist circumference.
* For systematic reviews/meta-analyses all confounders controlled for are included. All may not be included in each individual original study.

Table 7. Summary of studies on metabolic syndrome (MetS) risk in shift workers (SWs)

Study	Study type	Sex	Articles included	Type of SW	Exposure	Outcomes	Confounders controlled for*	Comment
Meta-analyses and systematic reviews								
Wang *et al.* (2014)[95]	MA	Male and female	13	Night	Variety of definitions of night work exposure. All included studies had time ranges of night work covering the period from 00.00 to 06.00 hours, with exception of one study	Criteria to diagnose MetS: NCEP ATP-III[98] (eight studies), IDF[97] (three studies), Japan Society for Study of Obesity criteria (one study), insulin-resistant components (one study)	Age, sex, education, SES, work organisation, duration of employment, BMI, WC, PA, job strain index, stress, sleep difficulties, smoking, alcohol consumption, carbohydrate intake, total energy intake, vegetable intake, snacking habits, diastolic BP, HDL-cholesterol, family history of MetS	MetS risk for ever exposed to night shift was 1·57 (95 % CI 1·24, 1·98; $P=0·001$)
Canuto *et al.* (2013)[96]	SR	Male and female	10	Night, rotating	Some studies did not explain how exposure data collected	MetS (as diagnosed by NCEP[98] or IDF[97] criteria), two studies used no definition	Sex, age, education, marital status, SES, smoking, PA, alcohol consumption, sleep, eating habits, diet	Insufficient evidence for association between SW and MetS when confounders taken into account

Study	Sex	Sample	Study duration	Number of follow-up events	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Cohort studies									
De Bacquer *et al.* (2009)[7]	Male	1529 (of which 309 SWs) Belgium	Median of 6·6 years follow-up	Baseline, plus follow-up after a median of 6·6 years	Rotating (two shift and three shift)	Work schedule, work conditions	MetS diagnosis based on medical examination, according to IDF[97] criteria	Age, smoking, high PA, education level, job strain, lifestyle	Increased incidence in SWs compared with day workers, with OR of 1·77 (95 % CI 1·34, 2·32). Dose–response relationship evident

Study	Controls	Cases	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Case–control studies							
Mohebbi *et al.* (2012)[94]	3039 (non-SW drivers)	3039 (long-distance SW drivers)	Rotating, night	Cases had minimum 2 years exposure to rotating/night SW. Controls matched for age, smoking history, current period of employment, average h/week in a year	Anthropometry, BP, fasting blood glucose, fasting blood lipid profile. (IDF[97] criteria)	Unspecified	With exception of BP, all components of MetS were significantly more prevalent among SWs *v.* day workers ($P<0·001$). MetS more common among SWs (OR 1·495; 95 % CI 1·35, 1·66)

Table 7 *Continued*

Study	Sex	Sample size	Population	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Cross-sectional studies								
Karlsson *et al.* (2001)[90]	47 % male and 53 % female	27 485	Mixed population (Sweden)	Unspecified	Experience of SW or working weekends, health behaviours	Anthropometry, BP, oral glucose tolerance test, lipid profile	Age, socio-economic group, PA, smoking, low social support, job strain	RR for SW *v.* day work: women with one, two and three metabolic variables were 1·06, 1·20 and 1·71. Corresponding RR for men were 0·99, 1·30 and 1·63. Prevalence of two or three metabolic variables significantly higher among SWs *v.* day workers ($P < 0.0001$)
Nagaya *et al.* (2002)[30]	Male	3650	Blue collar workers in transport/ manual/security industries (Japan)	Night	Usual work schedule, health behaviours	IR markers	Age, BMI, alcohol consumption, smoking, PA	SW may be associated with IR syndrome in workers <50 years of age
Sookoian *et al.* (2007)[91]	Male	1351	Factory workers (all of European ancestry)	Rotating	Current work schedule and work history, health behaviours	Anthropometry, BP, fasting blood glucose, fasting blood lipid profile (NCEP[98])	Age, socio-economic status, smoking, PA, alcohol, leucocyte count	Modestly increased risk of MetS in rotating SW (OR 1·51; 95 % CI 1·01, 2·25)
Esquirol *et al.* (2009)[19]	Male	198	Chemical plant employees (France)	Rotating	Work schedule, job strain, health and dietary behaviours	Anthropometry, BP, fasting blood glucose, fasting blood lipid profile (NCEP[98] and IDF[97])	Age, PA, job strain, smoking, alcohol consumption, dietary habits	Modestly increased risk of MetS in SW group (OR 2·4; 95 % CI 1·13, 4·98)
Puttonen *et al.* (2012)[92]	56 % male and 44 % female	1811	Airline workers (Finland)	Rotating, night. Also included former SWs	Current work schedule and work history, lifestyle behaviours	Anthropometry, BP, fasting blood glucose, fasting blood lipid profile (NCEP[98] and IDF[97])	Age, education, PA, alcohol consumption, smoking, insomnia	MetS diagnosed by standard criteria is more prevalent among male former SWs compared with male current day workers (OR 2·13, 95 % CI 1·35, 3·37). No significant difference for women
Ye *et al.* (2013)[93]	Female	254 (including 183 SWs)	Fabric industry workers (South Korea)	Rotating (two shift and three shift)	Work pattern, lifestyle habits	MetS as diagnosed by medical records (NCEP[98] adjusted for Korean population)	Age, alcohol consumption, PA	Prevalence of MetS was 15·3 *v.* 2·8 % for SWs *v.* day workers. Increased risk of MetS in the SW group (OR 6·30; 95 % CI 1·24, 32·15)

SW, shift work; MA, meta-analysis; NCEP ATP-III, National Cholesterol Education Program Adult Treatment Panel III; IDF, International Diabetes Foundation; SES, socio-economic status; WC, waist circumference; PA, physical activity; BP, blood pressure; SR, systematic review; RR, relative risk; IR, insulin resistance.

* For systematic reviews/meta-analyses all confounders controlled for are included. All may not be included in each individual original study.

The earliest of these studies noted that obesity, elevated blood TAG and low concentrations of HDL-cholesterol appeared to cluster together more often in shift workers than in day workers, indicating a potential association between shift work and components of the MetS[90]. Since then, further studies have assessed the risk of the MetS among shift workers, with cross-sectional data indicating a modestly increased risk of the MetS among this group[19,91–93]. In addition to this, case–control data have shown that all components of the MetS, with the exception of hypertension, are significantly more prevalent among shift workers[94]. As with obesity, a dose–response relationship has been observed, with increasing risk of the MetS with increased exposure to shift work[7,95]. Furthermore, the impact of previous shift work on health may persist even after disengaging from shift work, with data suggesting that the MetS may be more prevalent among former shift workers compared with current day workers[92].

However, difficulties have been identified when attempting to determine the association between the MetS and shift work among higher-quality studies. The results of one meta-analysis suggest a positive association between the MetS and having ever been exposed to night shift work, with higher risk indicated with longer exposure to night shift work[95]. However, in contrast, a recent systematic review, while finding that the majority of studies reported a positive association between the MetS and shift work, concluded that the evidence was insufficient to support an association once confounders were accounted for[96]. As well as a lack of control for confounders, issues with variability in defining both shift work and the MetS across studies were apparent. Among the included studies, different criteria have been used to define the MetS, with some studies using the International Diabetes Federation (IDF) criteria[97] and others using the updated National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP-III) criteria[98]. While the IDF includes the same general criteria as the NCEP ATP-III, the presence of central obesity is required to fulfil the definition of the MetS, with ethnic-specific values for waist circumference thresholds. Use of different criteria can make it difficult to compare studies, and it has been previously shown that use of NCEP ATP-III and IDF criteria for determining the MetS among shift workers can yield different results, with the IDF criteria finding a greater prevalence of the MetS compared with the NCEP ATP-III criteria[99].

Type 2 diabetes mellitus

The results of studies addressing shift work and risk of T2DM are presented in Table 8. Findings on disturbed postprandial glucose and lipid profiles among shift workers[24–26,100] suggest that shift work may induce insulin resistance, increasing the risk of T2DM. The regulation of glucose homeostasis is under circadian control, thus highlighting a potential link between chronic circadian misalignment and incidence of T2DM. Clinical studies have demonstrated that acute circadian misalignment (as little as 1–3 weeks) either alone or in conjunction with sleep restriction can cause the dysregulation of glucose homeostasis and postprandial impaired glucose tolerance[101–104]. Therefore, it could be assumed that continued or long-term disruption to circadian rhythms may increase the risk of T2DM.

Based on evidence from cohort studies, shift work appears to be a suggestive risk factor for T2DM, with slightly increased risk with shift work exposure after adjusting for confounders[105–109], particularly for rotating shift work[105–107]. In some cases, the association was mediated by body weight, with association between T2DM and shift work lost once adjusted for body weight[110]. Duration of exposure to shift work appears to be particularly important with regard to increasing risk[107,109]. Looking at higher-quality evidence, a systematic review of cohort studies reported moderate evidence for a positive association between shift work and T2DM; however, the low methodological quality of original studies was highlighted as a limitation[111]. Meanwhile, a meta-analysis of observational studies in the area found a modest increase in risk of T2DM for those ever exposed to shift work, and subgroup analyses found higher risk among men and those engaged in rotating shift work[112]. As before, methodological issues were highlighted, with heterogeneity across many of the original studies due to poor definitions of shift work and variability in shift work exposure. In addition there were inconsistent methods for defining diagnosis of T2DM as the outcome with varying diagnostic criteria used, or with some studies relying on self-reported T2DM diagnosis.

CVD

Occupational factors such as sleep duration and shift work have been suspected to be related to risk of CVD. The results from studies in the area are presented in Table 9. The hypothesis for a potential causal link proposes that metabolic changes, psychosocial stress and adverse health behaviours among shift workers may lead to increased CVD risk[113]. Although studies published over the past two decades suggest an impact of shift work on CVD risk factors, the data are not conclusive.

Observational evidence shows mixed results for an association between shift work and CVD. Modestly increased risk or suggestive evidence has been observed by some[114,115], with onset at younger ages among shift workers[114], or cumulative risk with extended periods of exposure[115]. In contrast, other studies indicate no evidence of an association between shift work and CVD[116] or increased risk compared with day workers[117], and the higher-quality studies have been unable to conclusively confirm an association. Two systematic reviews have indicated that data in the area suggest a modestly increased risk of CVD[100] or limited evidence for an association[113]. Both studies highlighted methodological issues in most of the included studies, such as selection bias, exposure and outcome classifications, controlling for confounders and inappropriate comparison groups. Overall, there appears to be suggestive but not conclusive evidence for a relationship between shift work and adverse CVD outcomes.

Gastrointestinal disorders

As early as the 1950s peptic ulcer disease was acknowledged as ‘the occupational disease of shift workers’[118]. There is

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Table 8. Summary of studies on type 2 diabetes mellitus (T2DM) risk in shift workers (SWs)

Study	Study type	Sex	Articles included (*n*)	Type of SW	Exposure	Outcomes	Confounders controlled for*	Comment
Meta-analyses and systematic reviews								
Gan *et al.* (2015)[112]	MA	Male and female	12	Mixed	Any SW	Diabetes mellitus	Age, sex, race, education, BMI, WC, smoking, alcohol, PA, diet, BP, total serum cholesterol, γ-GTP, uric acid, family history, menopausal status, hormone use, psychological distress, job strain, employment duration, social support	SW is associated with an increased risk of T2DM. The increase was significantly higher among men and the rotating shift group
Knutsson & Kempe (2014)[111]	SR	Male and female	5	Rotating, night	Any SW	T2DM	Age, BMI, smoking, PA, family history of T2DM	Moderate evidence of an association between SW and T2DM

Study	Sex	Sample	Study duration	Number of follow-up events	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Cohort studies									
Morikawa *et al.* (2005)[105]	Male	2860 factory workers (Japan)	8 years	Baseline and annual follow-up	Rotating	Work schedule, health behaviours, family history of T2DM	Incidence of T2DM (by HbA1c/ medical diagnosis)	Age, BMI, family history, smoking, alcohol consumption, PA	Significantly increased risk of T2DM found for two-SWs (RR 2·01, 95 % CI 1·00, 4·34) but not for three-SWs compared with white collar workers. Suggestive risk factor
Suwazono *et al.* (2006)[106]	Male	5629 steel company workers (Japan)	10 years	Baseline and annual follow-up at health examination	Rotating	Work schedule as verified by annual payment records	HbA1c, BMI, lifestyle factors, BP, serum cholesterol	Age, BMI, BP, alcohol, smoking, PA, total serum cholesterol, creatinine, uric acid, γ-GTP	Slightly increased risk of T2DM in SW group compared with day group (OR 1·35; 95 % CI 1·05, 1·75)
Kroenke *et al.* (2007)[110]	Female	62 574 nurses (USA)	6 years	Baseline and 2-yearly follow-up	Rotating	Work schedule history with a focus on rotating SW, job strain	Incidence of self-reported T2DM of which 98 % verified by medical records	Age, BMI, family history, job strain, PA, smoking, alcohol, fat intake, caffeine intake menopausal status, vitamin supplementation, aspirin use	Positive association between rotating SW and T2DM lost when adjusted for body weight
Pan *et al.* (2011)[107]	Female	177 184 nurses, two cohorts (USA)	18–20 years	Baseline and 2-yearly follow-up	Rotating	Years of exposure to rotating SW (defined as at least 3 nights/ month plus days/ evenings in that month), T2DM risk factors	Incidence of self-reported T2DM of which 98 % verified by medical records	Age, family history, BMI, alcohol, PA, smoking, menopausal status, hormone use, oral contraceptive use, aspirin use, total energy intake	After adjustment for multiple covariates, slight increase in risk of T2DM for every 5 years exposure to rotating SW (HR 1·05; 95 % CI 1·04, 1·06). Suggestive evidence
Poulsen *et al.* (2014)[108]	3% male and 97 % female	7305 health workers (Denmark)	7 years	Baseline to end point	Evening/night	Self-reported work hours	Incidence of T2DM gathered from Danish National Diabetes Register	Age, sex, ethnicity, physical and psychosocial work-related factors, BMI, PA, smoking, self-reported health and well-being score	Slight increase in risk of T2DM for evening/night SW *v.* day work (OR 1·27; 95 % CI 0·95, 1·70), risk mediated by obesity
Vimalananda *et al.* (2015)[109]	Female	28 041 African-American women (USA)	8 years	Baseline and 2-yearly follow-up	Night	Self-reported history of night SW, lifestyle behaviours, family history of T2DM	Self-reported diagnosis of T2DM of which 96 % verified by a physician	Age, family history, education, SES, BMI, PA, smoking, alcohol, energy intake, coffee and soda consumption	After adjusting for covariates, ever exposed to night SW carried slight increase in risk of T2DM (HR 1·12; 95 % CI 1·01, 1·23; *P*=0·022). Risk increases with increased exposure, for example, ≥10 years night SW (HR 1·23; 95 % CI 1·03, 1·47)

SW, shift work; MA, meta-analysis; WC, waist circumference; PA, physical activity; BP, blood pressure; γ-GTP, γ-glutamyl transpeptidase; SR, systematic review; HbA1c, glycosylated Hb; RR, relative risk; HR, hazard ratio; SES, socio-economic status.

* For systematic reviews/meta-analyses all confounders controlled for are included. All may not be included in each individual original study.

Table 9. Summary of studies on CVD risk in shift workers (SWs)

Study	Sex	Articles included (*n*)	Type of SW	Investigated	Outcomes	Confounders controlled for*	Comment
Systematic reviews							
Boggild & Knutsson (1999)[100]	Male and female	17	Mixed	CVD	Work pattern, morbidity and mortality from CVD, CVD biomarkers	Age, race, education, region, family status, smoking, alcohol, PA, sleep, weight, height, BP, diabetes mellitus, hypercholesterolaemia, work conditions, job strain	Methodological problems present in most included studies. 40 % increased risk associated with SW
Frost *et al.* (2009)[113]	Male and female	14	Mixed	IHD	Fatal/non-fatal coronary disease	Age, race, sex, social class, smoking, alcohol intake PA, BMI, family history of early-onset coronary disease, BP, blood cholesterol, diabetes mellitus	Limited evidence. RR ranged from 0·6 to 1·4 in twelve papers, two papers reported RR about 2·0

Study	Sex	Sample	Study duration	Follow-up events	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Cohort studies									
Brown *et al.* (2009)[115]	Female	80 108	16 years	Every 2 years	Rotating	Rotating SW history (total number of years exposure)	Fatal/non-fatal ischaemic stroke	Age, HTN, CHD, diabetes, cholesterol, aspirin use, BMI, smoking, alcohol, PA, fruit and vegetable intake, menopausal status, hormone therapy use	Every 5-year increment of rotating SW increased risk by 4 % (HR 1·04; 95 % CI 1·01, 1·07; $P=0·01$). Modestly increased risk after extended periods of rotating SW
Hublin *et al.* (2010)[116]	49 % male and 51 % female	20 142 (Finnish Twin Cohort)	22 years	Questionnaire × 2 (1975, 1981), follow-up for mortality to endpoint of 2003	Any shift	Working time (categorised as day/night/shift) assessed in 1975 and 1981, lifestyle covariates relevant to CHD	CHD mortality, disability retirement due to CVD, incident HTN	Age, marital status, social class, education, smoking, alcohol, HTN, BMI, PA, sleep	No significant association between SW and CVD mortality. Criteria to define SW not very specific and did not assess historical exposure to SW

Study	Controls	Cases	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Case–control studies							
Hermansson *et al.* (2007)[117]	469 day workers (5:1 controls: cases, age and sex matched)	138 SWs	Any type	Experience of SW, weekend work or variable working hours	Ischaemic stroke as measured by hospital/doctor reports, hospital discharge register, death certificates	Job strain, smoking, education level, serum TAG, total cholesterol, blood pressure	Crude OR for SWs' risk of ischaemic stroke 1·0 (95 % CI 0·6, 1·8) compared with day workers. Criteria to define SW not very specific and did not assess historical exposure to SW

Study	Sex	Sample size	Population	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Cross-sectional studies								
Haupt *et al.* (2008)[114]	(50 % male and 50 % female	2510	Representative German population including 698 former SWs	Night	SW exposure measured as dichotomous variable, length of exposure recorded, risk factors for CVD	Carotid intima-media thickness, self-reported physician's diagnosis of MI	Age, socio-economic status, sex, smoking, LDL-/HDL-cholesterol, HTN, diabetes mellitus	Multivariable Cox regression analysis identified SW as risk factor for MI to manifest at younger ages (adjusted HR 1·53, 95 % CI 1·06, 2·22)

SW, shift work; PA, physical activity; BP, blood pressure; RR, relative risk; HTN, hypertension; HR, hazard ratio; MI, myocardial infarction.
* For systematic reviews/meta-analyses all confounders controlled for are included. All may not be included in each individual original study.

evidence that circadian disruption affects the brain–gut axis, contributing to the pathogenesis of diseases and disorders of the gastrointestinal tract[119]. Important core functions of the gastrointestinal tract such as motility, maintenance and replacement of the protective barrier, and production of digestive enzymes may be disrupted, and such disruptions have been associated with gastrointestinal symptoms such as abdominal pain, constipation and diarrhoea[120]. Higher-quality data are lacking in this area. The only existing systematic review observed an increased risk of gastrointestinal symptoms, peptic ulcer disease and functional gastrointestinal disease among those engaged in shift work[8]; however, issues were noted with the original studies, with many being of poor quality or inadequately adjusting for confounders such as age, social class and exposure to known gastrointestinal irritants such as non-steroidal anti-inflammatory drugs. In addition only a small number of studies have addressed gastro-oesophageal reflux disease, inflammatory bowel disease and gastrointestinal cancers, all with inconclusive results.

Mental health and cognitive function

While the effect of shift work on physical health has been explored extensively, much less is published on its relationship with mental health. Shift workers may be more susceptible to depressive symptoms for a number of reasons, including disruption to the sleep–wake cycle, poor work–life balance, social desynchronisation, a demanding work environment with low control, and low levels of support at work. Social support from family and friends is also integral to preventing or reducing the impact of depressive disorders, and the social implications of shift work may weaken this crucial support network. In addition, the effect of light at night on mood has been a suggested hypothesis linking circadian disruption to major depression and other mood disorders[121].

Results of studies on depressive disorders and shift work are presented in Table 10. An association has been reported; however, the evidence is not particularly convincing[122,123]. Male shift workers over 45 years of age were identified as having the highest risk of developing depressed mood[123], while shift work was a predictor of suicidal ideation among female workers[124]. Duration of exposure to shift work is reported to increase risk for depressive disorders[122,125]; however, elsewhere mental disorders reportedly decreased with increasing shift work experience[126]. Exploration of mental health among shift workers is very much in the preliminary stages, and many of the available studies lack the use of a robust screening tool or fail to control for possible confounders.

The effect of shift work on cognitive performance has also been explored, with a theory of bidirectional interactions between circadian processes and cognitive performance suggested[127]. Investigations into the long-term consequences of chronic sleep deprivation showed male shift workers had lower cognitive performance than workers never exposed to shift work, with memory performance decreasing with increasing shift work duration[128]. A possible reversal of these effects was observed more than 4 years after cessation of shift work. However, more recent data from this ongoing longitudinal cohort study showed that shift work chronically impairs cognition, with a strong association for exposure duration exceeding 10 years. Again, it was shown that recovery of cognitive performance can occur 5 years after cessation of shift work[129]. The evidence is not conclusive, however, as another longitudinal study demonstrated no association between midlife shift work and long-term cognitive effects in older adults[130]. Reasons for the discrepancies in study results may relate to difficulties in assessing the true impact of shift work on brain function and cognition, due to problems distinguishing this impact from the influence of other related factors such as ageing and altered lifestyle behaviours. Unfortunately, clinical studies in this area are sparse.

Summary of the impact of shift work on health

Overall, it appears that shift work may have a negative impact on health, and the studies included in the present review more often than not showed a tendency towards increased health risk. Common also among many studies was the linear association between the duration of exposure to shift work and increased health risk. However, methodological issues were present in many of the studies, including the use of different measures of risk which increases the difficulty in interpreting and comparing results. To assess the true risk of these conditions for those engaging in shift work, it is necessary to standardise the definition of shift work, shift schedules and study outcome measures in order to provide high-quality evidence for associations between shift work and health risk.

Improving the lifestyle habits and health of shift workers

While other reviews have addressed lifestyle habits and health risks among shift workers[19,131,132], the present review goes beyond the range of those previously published, by exploring the barriers to improving lifestyle behaviours and the opportunities to promote health and reduce health risk among this group.

Barriers to a healthy lifestyle

The identification of existing barriers to change is necessary if the lifestyle habits of shift workers are to be improved. Data on this topic are sparse, with occupational sectors outside healthcare poorly represented. A number of studies have addressed barriers to healthy eating among occupations that typically involve shift work, such as medical and nursing staff[133–136]. The most commonly cited perceived barriers across studies were a lack of breaks, shift patterns, poor food selection, inadequate canteen opening times, lack of time and tiredness due to long working hours. Many shift workers are not provided with suitable meal options, sufficient time or appropriately spaced breaks in which to eat their meals in a relaxed environment. It has previously been shown that meal timing and content are constrained by task demands in the work place[137] and there is also evidence to show that eating on the night shift is driven more by scheduling constraints than by actual hunger[17]. Few workers felt that their employer was

Table 10. Summary of studies on mental health risk in shift workers (SWs)

Study	Sex	Sample	Study duration	Number of follow-up events	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Cohort studies									
Driesen *et al.* (2011)[123]	84% male and 16 % female	8890 (Netherlands)	10 years	1, 2 and 10 years follow-up	Night	Work schedule	Symptoms of depressed mood/disorder	Age, education, living alone, psychosocial work-related factors	Male SW ≥45 years higher risk of developing depressed mood (HR 1·37; 95 % CI 1·01, 1·86). Weak evidence

Study	Sex	Sample size	Population	Type of SW	Exposure	Outcomes	Confounders controlled for	Comment
Cross-sectional studies								
Scott *et al.* (1997)[122]	68 % male and 32 % female	98	Current and former SWs (USA)	Mixed	Work history	Psychiatric assessment instruments to detect lifetime incidence and current depressive symptoms	N/A	Increasing exposure to SW (up to 20 years) associated with increased lifetime risk of major depressive disorder. Suggestive evidence
Bazazan *et al.* (2014)[126]	Male	290	Petrochemical plant workers (Iran)	Rotating	SW experience (minimum 1 year)	Mental disorder status, psychological disorders, mental fatigue	N/A	Weak effect of occupational characteristics on mental disorders. Mental disorders decreased with increasing SW experience ($P=0{\cdot}048$). All data collected were self-reported
Khajehnasiri *et al.* (2014)[125]	Male	189	Oil refinery workers (Iran)	Rotating	Work history, SW experience	Depression	Age, BMI, marital status, education level, oxidative stress markers	Linear relationship between depression score and SW history ($P=0{\cdot}011$). Other work-related stressors not considered
Yoon *et al.* (2015)[124]	65% male and 35 % female	67 471	Nationally representative sample (Korea)	Night/any shift	Working hours, working conditions (day work *v.* night/shift work)	Suicidal ideation	Age, occupation, marital status, education level, income, smoking, alcohol, PA, co-morbidities, self-rated health	SW a significant predictor of suicidal ideation only among females (OR 1·45; 95 % CI 1·23, 1·70). Suicidal ideation increased significantly with increasing working hours. Limited evidence as just one question asked on suicidal ideation – lacking robust validated screening tool for mental health
Berthelsen *et al.* (2015)[149]	93 % male and 7 % female	1256	Petroleum industry workers (Norway)	Day/night/rotating	Shift schedule, duration of SW exposure, work-related factors	Anxiety and depression, psychological and social work factors, and neuroticism	Sex, age, education level, neuroticism	NS difference in mental stress between different shift schedule groups. Significantly higher levels of neuroticism among rotating SW compared with day SW ($F_{1,291} = 7{\cdot}821$; $P=0{\cdot}06$). All data collected were self-reported

SW, shift work; HR, hazard ratio; N/A, not available; PA, physical activity.

supportive of healthy eating[133–135], which again identifies the workplace as a key area for change in order to facilitate healthier lifestyle behaviours. The studies in this area highlight the need for workplace interventions that encourage well-designed work schedules and regular meal breaks, improved availability of healthy dining options and access to canteens at evenings and weekends. In addition, for some shift workers lack of nutritional knowledge may be a further barrier to healthy eating[134,135], presenting an opportunity for the provision of nutrition education tailored to shift work.

Meals outside the workplace should also be considered. Shift workers often experience a mismatch between their own routine and that of family and friends[137]. This may result in a variety of scenarios – dining with family in the evening and eating again later in work resulting in over eating, or choosing not to dine with family resulting in meals that are self-prepared and eaten alone, which can result in poorer-quality meals[138]. Disruption between work and home life routines may be particularly significant for women with children, who have a high off-job workload due to domestic duties, and often find themselves preparing family meals at times that are at odds with their own sleep pattern and appetite[38].

Opportunities for a healthier lifestyle

Workplace initiatives and careful management of shift work by employers can help minimise the deleterious effects of shift work on health and promote workers' wellbeing. Employers stand to gain from investing in the health of their employees, with costs minimised by reduced sickness and absence, reduced staff turnover, lower numbers of errors and accidents and their associated costs, and increased productivity[47]. As most adults spend approximately 60 % of their waking hours at work, worksites provide many opportunities to promote dietary and physical activity programmes and also have the opportunity to reach large populations[139]. Systematic reviews of studies involving workplace initiatives for promoting health among employees generally report short-term consistent modest reduction in weight, as a result of such interventions[140,141]. However, they also identify a lack of data on long-term health and economic outcomes and the dearth of good-quality research in this area, with many of the published studies limited by weak methodologies and difficulties with subject recruitment and retention.

Specifically in shift workers, Morgan *et al.*[139] conducted a prospective randomised controlled trial for a workplace-based weight loss programme targeting overweight and obese male shift workers. The intervention group had significant reductions in weight, waist circumference, BMI, systolic blood pressure and resting heart rate, and a significant increase in physical activity. This programme was successful despite a low level of face-to-face contact. Online support meant that participants could access support and information at their convenience, a feature which may be particularly appealing to shift workers. Further opportunities to improve health, such as health screening, may also be beneficial to the shift work population. Viitasalo *et al.*[142] showed that screening for T2DM and CVD among airline employees effectively identified employees with an increased risk who would benefit from lifestyle intervention. However, the benefits of regular health screening of shift workers for markers of chronic diseases requires further exploration before recommendations can be made.

Conclusion

A recurrent theme in the literature is the lack of a standardised definition for shift work and the variability in shift patterns. This, along with inter-study variability in methods to define shift work exposures and outcomes, and poor control for confounding factors, impairs the ability to clearly demonstrate associations between shift work and lifestyle or health risks. Nonetheless, a trend towards shift work being associated with negative outcomes for lifestyle behaviours and health risks is apparent. It is evident that there is a lack of information on the barriers to health and the opportunities for effective health improvement and promotion among this group. This warrants investigation, in order to help those engaging in shift work to overcome associated occupational hazards and lead a healthier lifestyle. The current prevalence of non-communicable diseases and mental health disorders in society, coupled with a workforce where shift work is increasingly prevalent, means that addressing the associated health risks is important in terms of both public and occupational health, and economic and personal cost. Identifying the barriers and opportunities for improving health will help to direct health promotion to this group, enabling the implementation of effective interventions such as nutrition and lifestyle education and workplace health-promotion programmes, which will serve towards making the healthier choice more accessible to all employees.

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