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REVIEW ARTICLE

Healthy Diet and Reduction of Chronic Disease Risks of Night Shift Workers

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Abstract: ***Background*:** The large increase in epidemiological studies on night shift work is due to the important effects of night shift work on workers' health and psychophysical wellbeing. The short-term effects—insomnia, difficulties in managing work and private life, lower work performance, and more work and extra-work accidents—are easily studied. However, there are several long-term effects that are difficult to study because of the need for detailed exposure assessment and the long latency periods of these diseases.

***Objective*:** The aim was to collect epidemiologic evidence of diseases in night shift workers, describing their biological pathways and a set of dietary guidelines.

***Method*:** This is a review on diet and health effects in night shift workers.

***Results*:** Significant increases in the rate ratios and hazard ratios of different diseases were associated with modified eating behaviours and poor eating habits among night shift workers. Night shift work is a risk factor for disruption of the circadian rhythms and for some genetic deregulation because it produces the inversion of the sleep/wake cycle and modifies the alternation between activity and rest.

***Conclusion*:** A healthy diet and improved dietary practices, together with other factors, can reduce shift workers' chronic disease risk. The literature showed the importance of eating behaviour in order to prevent diseases in these workers; therefore, educational programmes are necessary to encourage several important lifestyle changes. The target of our future research will be the role of food components in some dietetic habits for the prevention of disease in night shift workers.

Keywords: Night shift work, health effects, shift lag syndrome, chronic disease, eating behaviour, dietary guidelines.

1. NIGHT SHIFT WORK

In industrialized countries, most workers are shift workers [1].

In the European Union, 20-30% of workers perform shift work and the numbers are increasing because of the new economic and technological needs of the so-called "24-hour society" [2].

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Shift work is growing not only in the industrial and emergency sectors but also among "white collar" workers.

Shift work consists of day, afternoon and night shifts. Shifts are common in several occupations: industrial activity, mines, the healthcare sector, police, firefighters, hotels, food service and the transport sector.

In Europe, the highest prevalence of night work (>5 nights/month) is among the hotel/restaurant, transport and healthcare sectors (Fig. **1**) [3]. Modern 'call centres', the financial sector, supermarkets, restaurants, petrol stations, and grocery stores are increasingly

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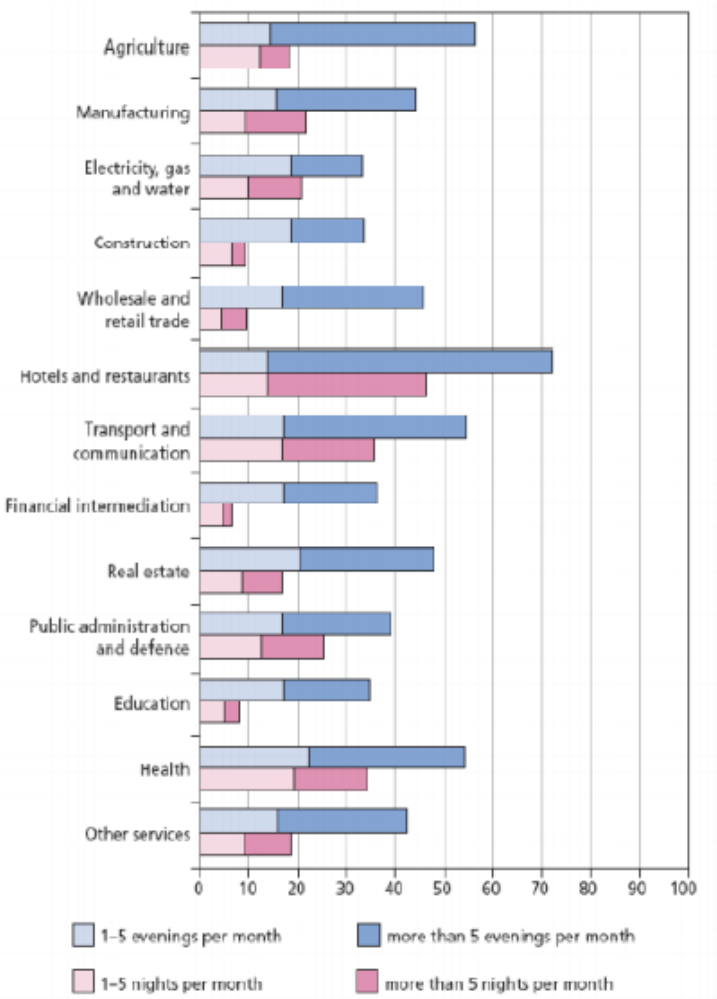


Fig. (1). Prevalence of evening and night work sector in Europe in 2005 (4th EU Survey on working conditions). (Source: WHO. IARC. Painting, Firefighting and Shiftwork. IARC Monograph on the Evaluation of Carcinogenic Risks to Humans. Vol 98. LYON FRANCE. 2010)

based on shift work. In addition, workplaces where the constant operability of technical processes based on expensive equipment is a guarantee of product quality are based on a shift work organization.

There are both women and men shift workers. However, there are sex differences in the occupational sector: most women work in the healthcare sector, and most men are employed in manufacturing.

Many workers are employed with irregular working hours, night shift work, weekend work, telework, part-time work, and flexible work time. Instead, few workers carry a regular work time (7-8 a.m. to 5-6 p.m., Monday to Friday).

The ageing workforce will increase the amount of older shift workers [4]. Shift workers have more health problems than day workers [5,6].

According to the International Labour Office (ILO), working in shifts allows the company to operate 24 hours a day because workers alternate among the shifts [7].

The European Council (Directive number 93/104) declared that shift work means an organized work schedule where workers make shifts according to a pattern. [8].

Any work involving irregular or unusual hours, which does not occur during daily hours (6 a.m. to 6 p.m.), is classified as “shift work”.

The work shift can be continuous (24 hours per day, 7 days per week) or semi-continuous (2 or 3 shifts per day with or without weekends).

The length of a shift can vary between 8 and 12 hours. A further classification based on the duration of the shift is possible.

Permanent shift work: one shift only.

Rotating shift work: alternation of different shifts.

Table 1. Definitions of night work and night worker in some European countries.

Country	Night Time/Nightwork	Night worker
AUSTRIA	Night work: period between 22:00 and 05:00	The workers who work at least 3 hours between 22:00 and 05:00 on at least 48 nights per year (EU-NachtarbeitsAnpassungsgesetz 2002)
BELGIUM	Night work: a period, generally of 8 hours, between 20:00 and 06:00	Loi du 17/02/1997 et Loi du 04/12/1998: Act of 17 February 1997
FINLAND	Night work: period between 22:00 and 05:00	Night shift refers to a work shift with at least 3 hours of duty between 23:00 and 06:00 (Working Hours Act 605/1996)
FRANCE	Night time: a period between 22:00 and 05:00. Night work: whichever work period between midnight and 05:00	Any employee working usually at least 2 times per week for at least 3 hours over the period defined as night work (Loi 461/1998).
GERMANY	Night time: the time between 23:00 and 06:00 (in case of bakers between 22:00 and 05:00) Night work: all work which occupies more than 2 hours of night time.	"Night workers" means workers who usually work nights on rotating shifts schedules, or work at night for not less than 48 days in a calendar year (Arbeitszeitgesetz 1994)
GREECE	Night time: a period of 8 hours which includes the period between 22:00 and 06:00	A worker who during night time works at least 3 hours of his/her daily working time or a worker who has to perform night work for at least 726 hours of his/her annual working time (Presidential Decree n. 88/1999).
IRELAND	Night time: period between midnight and 07:00	a) an employee who normally works at least 3 hours of his/ her daily working time during night time; b) an employee whose working hours during night time, in each year, equals or exceeds 50 per cent of the total number of hours worked during the year (Statutory Instruments n. 485/1998).
ITALY	Night work: the activity carried out in a period of at least 7 consecutive hours comprising the interval between midnight and 05:00	a) any worker who during the night period carries out, as a normal course, at least 3 hours of his/her daily working time; b) any worker who during the night period, carries out part of his/her daily working time as defined by collective agreements; in default of collective agreements, any worker who works at night at least 80 working days per year (D.Lgs. 66/2003).
NETHERLANDS	Night work: work which covers all or part of the period from midnight to 06:00	
PORTUGAL	Night time: a period between 20:00 and 07:00	a) any worker who works at least 3 hours during the night period; b) any worker who during the night period, carries out part of its daily working time as defined by collective agreements (Decreto Lei 73/1998)
SPAIN	Night time: a period which includes the interval between 22:00 and 06:00	A worker who at night carries out at least 3 hours of his/her daily working time (Real Decreto Lei 1/1995).
SWEDEN	Hours between midnight and 05:00	A worker that works at least 3 hours of his/her daily work during night time, or a worker that most likely will work at least 38% of his/her annual work during the night (Working Hours Act 1982).
UK	Night time: a period lasting not less than 7 hours, and which includes the period between midnight and 05:00	A worker who, as a normal course, works at least 3 hours of his/her daily working time during night time, or who is likely, during night time, to work at least such proportion of his annual working time as may be specified for the purposes of these Regulations in a collective agreement or a workforce agreement (Statutory Instrument No.1833/1998).

(Source: WHO. IARC. Painting, Firefighting and Shift work. IARC Monograph on the Evaluation of Carcinogenic Risks to Humans. Vol. 98. LYON FRANCE. 2010).

Discontinuous shift work: every day of the week except weekends or Sundays.

Continuous shift work: all days of the week.

With or without night work: all or part of the night, all or some nights per week/month/year.

There are also differences in the night periods among European countries (Table **1**) [3].

2. EPIDEMIOLOGICAL EVIDENCE

Recently, shift work was recognized as a health risk factor; in particular, it can predispose an individual to cancer [9].

A correlation was found between shift workers' diseases and the age at which night shift work was performed [10] (Fig. **2**).

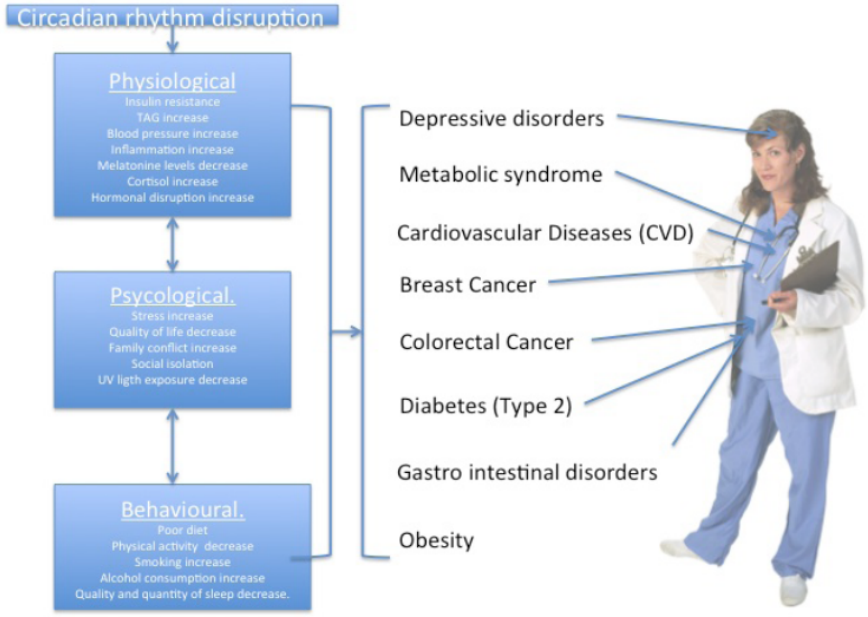


Fig. (2). The potential pathways to diseases due to the shift work circadian rhythms disruption.

Some common effects are insomnia, fatigue [11], cardiovascular diseases [5], and depressive symptoms [12].

These effects can be explained by the alteration of the circadian rhythm of the sleep/wake cycle, which makes performance optimal during daily hours. If there is a frequent desynchronization of this rhythm, there will be health disorders. Social activities will also be affected [13].

Shift work is associated with nutritional and metabolic disorders, increased body mass index and obesity.

Many studies have shown a high prevalence of obesity and overweight rates and fewer people who follow a Mediterranean diet in both Mediterranean and non-Mediterranean areas. These studies analysed people working at night and their dietary, smoking and alcohol habits, physical activity, sleep and health disorders.

Night workers have a poorer diet due to the quality and irregular timing of meals. In particular, they often eat snacks rather than a full, well-balanced meal. Additionally, they do not eat with family.

The frequency of meals is reduced, while night shift workers more frequently eat snacks and consume drinks with caffeine to stay awake [9].

Aside from obvious fatigue, other effects include the following:

"Shift-lag syndrome", which is a group of symptoms such as sleeping and gastrointestinal disorders, tiredness, and poor job performance [14,15];

Gastrointestinal disorders characterized by constipation, digestive difficulties, flatulence, heartburn, stomach ache, loss of appetite, gastroduodenitis, ulcer, or irritable bowel syndrome [16];

Decreased quality of life: shift workers have difficulties in managing social and family relationships. This fact leads to a poor social life. Childcare facilities can help shift workers with family, but they are few in number [15];

Associations between night shift work and chronic diseases are less clear and difficult to study, given the need for detailed exposure assessment and a long follow-up to ascertain chronic disease outcomes [15,17,18].

2.1. Cardiovascular Diseases (CVD)

Few studies have examined the relationship between shift work and cardiovascular diseases (CVD), but overall they show an adverse association [19-21].

The risk of coronary heart disease in shift workers has been reported, but the data are not clear [22]. An increased risk of myocardial infarction has also been found [23]. Other results have highlighted associations between working at night and in the early morning with CVD risk factors [24]. In a study related to shift workers on a cocoa farm, the "Framingham risk score" was applied. This cardiovascular risk score was useful to estimate the CVD risk within 10 years (low risk is 10% or less CVD risk, intermediate risk is 10-20% CVD risk, and high risk is 20% or more CVD risk) [25].

Table 2. The Framingham Study risk score for shift and non shift workers.

Works	Risk score (%)			
	Low risk	Moderate Risk	High risk	Total
Shift workers	79	21	0	100
Non-shift workers	84	16	0	100

(Sources: Asare-Anane, H.; Abdul-Latif, A.; Ofori, E.K.; Abdul-Rahman, M.; Amanquah, S.D. Shift work and the risk of cardiovascular disease among workers in cocoa processing company, Tema. *BMC Res Notes*, 2015, 8, 798.).

According to the Framingham score, shift workers in a Cocoa Processing Company (CPC) showed an intermediate CVD risk, probably due to fewer biochemical risk markers in workers' blood samples depending on the consumption of cocoa products by the factory workers (Table **2**) [26]. More recently, a systematic review found that the correlation between shift work and CVD was inconclusive. [27]. Studies about the relationship between shift work and ischaemic heart disease (IHD) incidence or mortality showed inconsistent results [24,28]. However, two follow-up studies [19,29] and a recent meta-analysis [30] found a stronger association between IHD and night shift work than with other kinds of shift work. A cohort study of 504 paper mill workers found an increased risk of IHD within a period of 10 years of shift work [31]. The Nurses' Health Study (NHS) cohort of night shift workers showed an increased risk of coronary heart disease [29].

Three of five studies on the duration of shift work reported increased risks after many years of shift work [19,29,33], with the exception of two case-control studies [32-34].

Increased all-cause mortality and CVD were observed in a large cohort of nurses working in the night shifts for more than 5 years.

An increased mortality for IHD was found among female night shift workers, while there was no increased risk for cerebrovascular disease or other CVDs.

The association between CVD and rotating night shift work remained statistically significant among those who had never smoked [35]. According to the Royal College of General Practitioners (RCGP) system, the association between shift work and CVD was moderate [1].

Early morning work is also associated with an increased CVD risk [24].

2.2. Ischaemic Stroke

One study showed that the risk of ischaemic stroke increased among nurses who rotated night shifts for 15 or more years [37]; although another study did not find this association [36].

In a large cohort study of 80,108 subjects, 60% had been night shift workers for at least 1 year; 1,660 had ischaemic strokes (4%).

The risk of stroke after many years of night shift work seems to be modestly increased in women [37].

2.3. Metabolic Syndrome

Obesity, hypertension, elevated triglycerides, and elevated cholesterol [38] are generally associated with metabolic syndrome [38]. The Third Report of the National Cholesterol Education Program and other societies (NCEP-ATPIII, IDF, WHO and others) provided four main definitions of metabolic syndrome [39-43].

The risk of metabolic syndrome, in particular related to obesity, hypertension and high values of triglycerides [44], was shown to be increased among shift workers, as demonstrated by Sookoian *et al.* [45].

Among rotating shift workers in a petrochemical plant, a higher risk of metabolic syndrome was reported [46].

The same results were reported by two prospective studies [47,48].

In the same industrial context, for females and males with elevated levels of serum alanine aminotransferase, the same results were reported [49,50].

Among police officers who worked midnight shifts, there was no increased risk of metabolic syndrome observed compared to the day workers because their unusual daytime shift started at 4:00 a.m. [51].

Another study showed that age, sex, perceived stress, sleep disorders and socioeconomic conditions of shift workers were associated with metabolic syndrome [17].

2.4. Diabetes

Although there are few studies in the literature, an association was found between shift work and diabetes

in Japanese male factory workers [52,53]. In particular, shift workers aged 30–39 years had high fasting serum glucose (7 mmol/l) or received treatment for diabetes [54].

The number of years of shift work was positively associated with the risk of diabetes among pulp and paper industry workers [33].

However, no association was found among Japanese male factory workers [55].

Additionally, when adjusted for age, night shift work was associated with an increased risk of type 2 diabetes [56], but this association was eliminated after adjusting for body mass index [57].

Metabolic syndrome is a serious risk factor for diabetes [15,18].

2.5. Obesity

Several studies have detected an increased body mass index (BMI), overweight or obesity among shift workers [44,58-61]. Other studies were not able to find positive associations [62,63] or found a negative association [64]. However, most studies have included blue collar workers or nurses and not a larger, mixed cohort of workers [59].

The risk of becoming overweight and obese has been shown to increase with the duration of shift work [65,66].

Recent studies have shown an increase in obesity among shift workers by analysing BMI [44,58,67,68].

This association was also found only in male and manual workers, using the data from the Korea National Health and Nutrition Examination Survey (KNHANES), which aims to measure obesity by means of the Total Body Fat Percentage (TBF%) and to evaluate the risk of obesity in Korean wage shift workers [69]. A high risk of obesity has also been found in shift workers in Ontario [70].

Obesity was spread among Korean female workers, regardless of the number of hours worked per week and the type of work; only non-manual female workers showed an increased risk of obesity if they worked at night [71].

In a cross-sectional study of municipal workers, a multiple regression model indicated that shift schedules and other factors (physical activity, occupation, age, gender, race, and HbA1c) were significant predictors of obesity ($p < 0.01$) [72].

2.6. Cancer

In 2007, the World Health Organization (WHO) stated that shift work is "probably carcinogenic".

Different studies found that night work increased the risk of breast cancer by 50%. Working shifts on airplanes, as pilots and flight attendants do, increased the risk by 70%. There is some evidence that shift work might increase the risk of colorectal and prostate cancer as well [1].

In 2007, the International Agency for Research on Cancer (IARC) classified shift work and night work as probably carcinogenic to humans (Group 2A) because of sufficient evidence in animals of the carcinogenicity of light during the daily dark period (biological night), adding a new potential pathogenic factor to diseases correlated with shift work and night work [73]. The IARC focused on studies of night workers who showed an increased risk for breast cancer over women who did not work at night; they were mainly nurses and flight attendants.

Exposure to light at night can cause disruption of the circadian system; it can alter the sleep/wake cycle, suppress melatonin production and deregulate oncogenes [1]. In particular, night shift work is the most dangerous shift for the circadian rhythm. The risk of breast cancer has been analysed in shift workers [56,74-80] and flight attendants [81]. According to a review published in 2008, there was limited evidence of the associations between night shift work and breast cancer, prostate cancer and colon cancer [82].

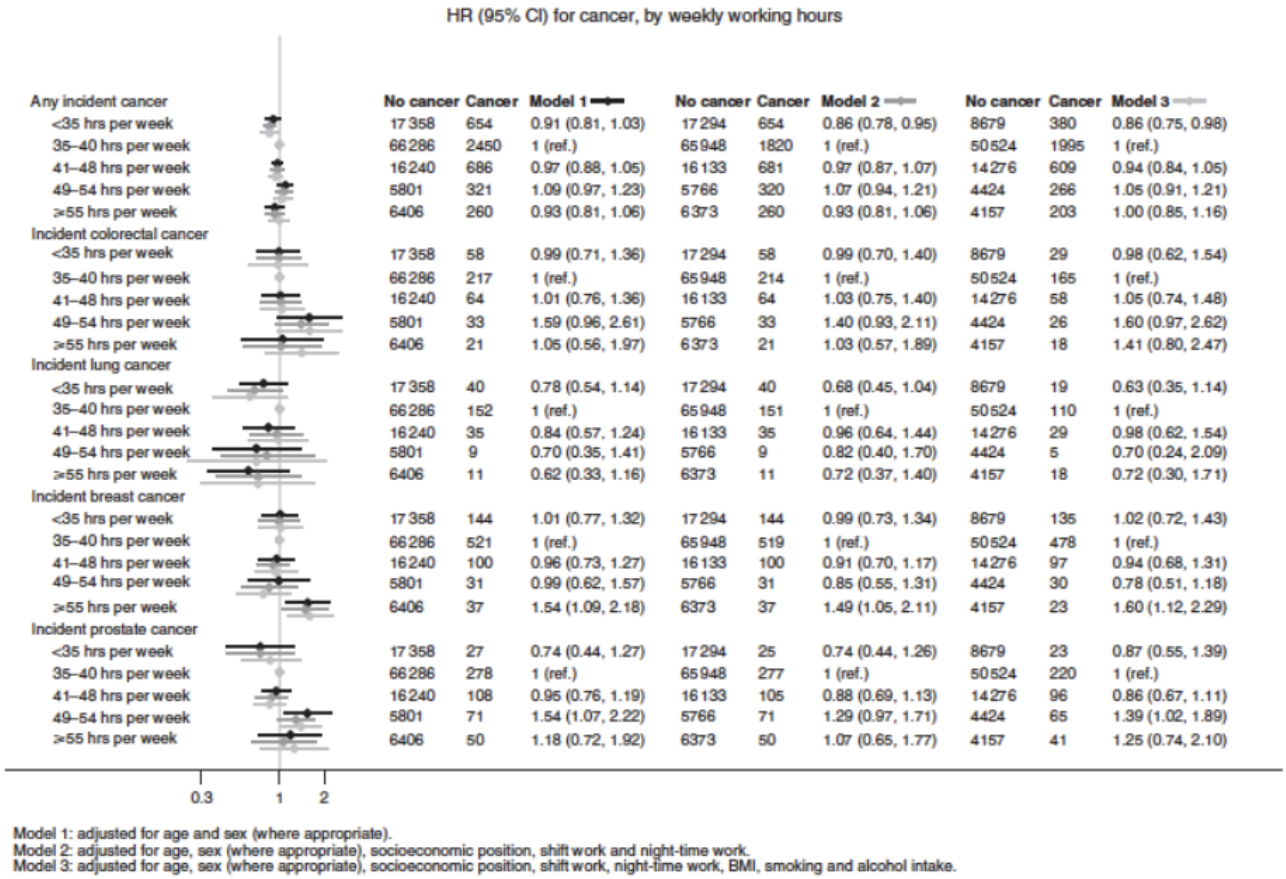
However, recent studies found that a long working schedule was associated with breast cancer but not with all cancers (Fig. **2**) [83].

2.6.1. Breast Cancer

Megdal *et al.* carried out a meta-analysis about night shift work and breast cancer in 2005. They found a significant association [81].

Six studies found a modestly increased risk of breast cancer among night shift workers [73]. A study of the U.S. National Health System reported that nurses working more than 30 years of night shifts had a breast cancer risk approximately 36% higher than workers who did not work night shifts [77]. Nurses working more than 20 years of night shifts also had an elevated risk of breast cancer [56].

However, there are few studies on the association between night shift work and breast cancer, and the phenomenon has been studied mostly among nurses [82].



	No cancer	Cancer	Model 1	No cancer	Cancer	Model 2	No cancer	Cancer	Model 3
Any incident cancer									
<35 hrs per week	17358	654	0.91 (0.81, 1.03)	17294	654	0.86 (0.78, 0.95)	8679	380	0.86 (0.75, 0.98)
35–40 hrs per week	66286	2450	1 (ref.)	65948	1820	1 (ref.)	50524	1995	1 (ref.)
41–48 hrs per week	16240	686	0.97 (0.88, 1.05)	16133	681	0.97 (0.87, 1.07)	14276	609	0.94 (0.84, 1.05)
49–54 hrs per week	5801	321	1.09 (0.97, 1.23)	5766	320	1.07 (0.94, 1.21)	4424	266	1.05 (0.91, 1.21)
≥55 hrs per week	6406	260	0.93 (0.81, 1.06)	6373	260	0.93 (0.81, 1.06)	4157	203	1.00 (0.85, 1.16)
Incident colorectal cancer									
<35 hrs per week	17358	58	0.99 (0.71, 1.36)	17294	58	0.99 (0.70, 1.40)	8679	29	0.98 (0.62, 1.54)
35–40 hrs per week	66286	217	1 (ref.)	65948	214	1 (ref.)	50524	165	1 (ref.)
41–48 hrs per week	16240	64	1.01 (0.76, 1.36)	16133	64	1.03 (0.75, 1.40)	14276	58	1.05 (0.74, 1.48)
49–54 hrs per week	5801	33	1.59 (0.96, 2.61)	5766	33	1.40 (0.93, 2.11)	4424	26	1.60 (0.97, 2.62)
≥55 hrs per week	6406	21	1.05 (0.56, 1.97)	6373	21	1.03 (0.57, 1.89)	4157	18	1.41 (0.80, 2.47)
Incident lung cancer									
<35 hrs per week	17358	40	0.78 (0.54, 1.14)	17294	40	0.68 (0.45, 1.04)	8679	19	0.63 (0.35, 1.14)
35–40 hrs per week	66286	152	1 (ref.)	65948	151	1 (ref.)	50524	110	1 (ref.)
41–48 hrs per week	16240	35	0.84 (0.57, 1.24)	16133	35	0.96 (0.64, 1.44)	14276	29	0.98 (0.62, 1.54)
49–54 hrs per week	5801	9	0.70 (0.35, 1.41)	5766	9	0.82 (0.40, 1.70)	4424	5	0.70 (0.24, 2.09)
≥55 hrs per week	6406	11	0.62 (0.33, 1.16)	6373	11	0.72 (0.37, 1.40)	4157	18	0.72 (0.30, 1.71)
Incident breast cancer									
<35 hrs per week	17358	144	1.01 (0.77, 1.32)	17294	144	0.99 (0.73, 1.34)	8679	135	1.02 (0.72, 1.43)
35–40 hrs per week	66286	521	1 (ref.)	65948	519	1 (ref.)	50524	478	1 (ref.)
41–48 hrs per week	16240	100	0.96 (0.73, 1.27)	16133	100	0.91 (0.70, 1.17)	14276	97	0.94 (0.68, 1.31)
49–54 hrs per week	5801	31	0.99 (0.62, 1.57)	5766	31	0.85 (0.55, 1.31)	4424	30	0.78 (0.51, 1.18)
≥55 hrs per week	6406	37	1.54 (1.09, 2.18)	6373	37	1.49 (1.05, 2.11)	4157	23	1.60 (1.12, 2.29)
Incident prostate cancer									
<35 hrs per week	17358	27	0.74 (0.44, 1.27)	17294	25	0.74 (0.44, 1.26)	8679	23	0.87 (0.55, 1.39)
35–40 hrs per week	66286	278	1 (ref.)	65948	277	1 (ref.)	50524	220	1 (ref.)
41–48 hrs per week	16240	108	0.95 (0.76, 1.19)	16133	105	0.88 (0.69, 1.13)	14276	96	0.86 (0.67, 1.11)
49–54 hrs per week	5801	71	1.54 (1.07, 2.22)	5766	71	1.29 (0.97, 1.71)	4424	65	1.39 (1.02, 1.89)
≥55 hrs per week	6406	50	1.18 (0.72, 1.92)	6373	50	1.07 (0.65, 1.77)	4157	41	1.25 (0.74, 2.10)

Fig. (3). Association of weekly working hours with incident cancer. (Source: Heikkila K *et al.*, 2016. Long working hours and cancer risk: a multi cohort study. British Journal of Cancer (2016) 114, 813-818.)

Female breast cancer risk is increased when the working hours are 55 per week, regardless of confounding factors such as age, socioeconomic conditions, and kind of work shift (Fig. **3**) [83].

2.6.2. Prostate Cancer

There are few studies on the association between shift work and prostate cancer [80,84,85].

One study did not find a significant association between shift work and prostate cancer [80].

However, Kubo *et al.* found a positive association, with a 3 times increased risk of prostate cancer among men working with rotating shifts [84], as did Conlon *et al.* [85].

2.6.3. Colorectal Cancer

The association between shift work and colorectal cancer is also limited.

A Swedish cohort study did not find a significant association [80]. Additionally, among telegraph operators in a more recent Norwegian study, no significant associations were found [56].

Nevertheless, nurses working at least three nights per month for 15 years or more had a moderately increased risk of colorectal cancer [80,82,56].

2.6.4. Lung Cancer

There was a significant association between night shift work and mortality for lung cancer [35].

However, another study did not show this association. Instead, rotating night shift work, adjusted for smoking habits, was associated with a relatively reduced lung cancer risk, although this was not statistically significant [86].

2.6.5. Cancer at Other Sites

Lahti *et al.* found an increased risk of non-Hodgkin lymphoma in a Finnish cohort of night shift workers [87].

3. HEALTH EFFECTS, DIET AND NIGHT SHIFT WORK

Diet and eating behaviour patterns are important factors for health and the prevention of disease.

"You are what you eat" is a phrase often used to describe the compromised metabolic health associated with the excessive intake of food with limited nutritional value. Our endogenous circadian clocks may reflect what we eat and our ability to adjust to shift-lag after a sleepless night [89].

Shift workers develop 'shift-lag' syndrome and recover in a few days depending on the length and duration of the imposed shift phase, personal characteristics (*e.g.*, age), and their coping strategies.

Night work, *e.g.*, the period of a minimum of 7 consecutive hours between midnight and five am, represents a source of risk for workers' health. In fact, the human body is more vulnerable during those hours, which usually should be directed to sleep. The various negative effects on the human body can be grouped into three different levels: working, social and familiar, and biological [6].

Working shifts, especially night work, might alter eating behaviours. It has been suggested that night work causes a conflict between socially determined meal schedules and the circadian biological rhythms for hunger, satiety and metabolism. Nocturnal eating causes disorders of intestinal motility, affecting the digestion, absorption, and utilization of pharmacological drugs and nutrients.

From a chronobiological point of view, the human species is active during the day and therefore has a low appetite at night, when the organism is programmed for restitution, fasting, and endogenous mobilization of blood glucose [90,91].

According to Zhao *et al.*, the percentage of body fat mass, waist circumference, energy intake, impaired sleep, lower insulin sensitivity, triglycerides and C-reactive protein increased among night shift workers [92].

Shift workers have altered eating habits, a higher energy intake and an increased consumption of saturated fatty acids and foods with a high glycaemic index [93,94].

From a psychosocial perspective, shift workers commonly experience a mismatch between their daily routines (including meal times) and those of family and friends, which may disrupt their eating habits. The eating behaviour of shift workers also depends on local cultural norms (*e.g.*, the number and timing of daily eating events and what is typically eaten at certain times) [95]. Finally, eating at night might improve wellbeing but simultaneously impair metabolism.

Hunger and satiety hormones are linked to circadian rhythms in metabolism in order to facilitate nocturnal fasting and sleep. This may account for the depressed appetite that is often observed during night work.

Shift workers' eating behaviour may also affect their neural functioning. Short-term changes in food intake are known to affect many aspects of cognitive performance, mood, and wakefulness [2,12]. For example, the cognitive-behavioural consequences of both short- and long-term restrictions of food intake (*e.g.*, skipping meals or incomplete food composition and fasting, dieting, and malnutrition, respectively) have been observed. Short-term effects are related to a lack of energy supply, while long-term effects concern a lack of the supply of essential nutrients (*i.e.*, vitamins, minerals, and essential amino and fatty acids) that are necessary for the functioning of the senses and biochemical processes [96].

As previously seen, an increased prevalence of poor eating habits and gastrointestinal distress among shift workers likely contributes to hypertension, obesity, metabolic syndrome, cardiovascular disease (CVD), diabetes and cancer [97,98]. A recent review highlights the increased consumption of calories, fats, carbohydrates and sweets among shift workers compared to non-shift workers [96].

Shift workers' diets were found to be richer in animal fats and proteins. However, night workers consumed more energy at work (due to a larger proportion of fat and carbohydrate intake) when compared to the other workers; instead, the consumption of dietary fibre was reduced due to a reduction in the consumption of green vegetables and an increase in sucrose from a higher intake of soft drinks. Linseisen *et al.* found that the intake of dietary fibre and sources of zinc and vitamins A and D was reduced to below the daily recommended levels in a group of permanent night workers [99]. This might be an effect of altered meal patterns or food choice where, for example, the preparation of hot meals including a variety of foods is reduced and replaced by the ingestion of single food items or bread-based meals.

Several studies have also reported that workers on the night shift tend to eat more frequently, with multiple snacks commonly being eaten during the night shift instead of a full meal [95]. Nyberg [100] concluded that the eating habits of shift workers could be described as consuming "plenty of food but few meals". There is the tendency for night workers to consume easy-to-prepare food characterized by a high energy content. Shift work appears to affect the amount eaten,

quality of the dietary intake, and energy distribution over the course of the day.

Several studies have reported a greater tendency to eat small amounts frequently ("nibbling behaviour") during the night shift. Additionally, eating tends to be more irregular during the night shift period; moreover, there may be an increase in the consumption of coffee and other drugs that supposedly help maintain wakefulness at night, but which may also contribute to the development of gastric problems or other illnesses [100].

The synchronization of human life is associated with meal times, which are a physiological and social regulator. Shift work can change food timing, and a healthy diet can be difficult to maintain. Research has shown that shift workers had more eating events per day than day workers [9,96]. Night shift workers ate more snacks compared with day workers.

Shift workers change the timing and frequency (*i.e.*, nibbling) of eating, as well as the content of meals (more fats and carbohydrates), often eating food cold and during short breaks (snacking). After sleeping, digestive troubles are the most frequently complained about by shift workers (20-75% vs. 10-25% of day workers). This is due to the alteration of mealtimes and normal circadian phases of gastrointestinal functions (*e.g.*, gastric, bile and pancreatic secretions, enzyme activity, intestinal motility, rate of absorption of nutrients, and hunger and satiety hormones) and to changes in food quality and composition and unbalanced diet (*i.e.*, more pre-packaged food and soft drinks). The quality and timing of meals, nibbling, and disturbed socio-temporal patterns, such as work and non-work conflicts, are related to higher stress levels [9,96]. Knutson discovered that after workers had changed from day work to shift work, they increased the consumption of soft drinks and sucrose intake and decreased their intake of vegetables and fibre [16].

Gender differences related to dietary habits Shift workers eat fewer vegetables and fruits. In women, energy intake from saturated fats was higher among shift workers compared with day workers [101]. In older females, the consumption of energy was higher in shift workers and in-flight workers. Night workers' energy intake from fats, fruits and vegetables was higher and energy intake from bread and meats was lower than that of day workers [101].

The general energy intake of shift workers is not different from that of day workers.

Shift work may have an impact on diet quality: increasing the intake of saturated fats and decreasing the intake of polyunsaturated fats, dietary fibre, and vitamins A, D, E and Zn [102].

The type of job, work environment and availability of food in the workplace are important determinants of the dietary habits of shift workers. Availability influences most types of foods consumed. A higher consumption of energy-dense foods, generally provided by vending machines, has been strongly reported [96]. Work schedule and the availability of food are able to modify the dietary habits of shift workers. Eating behaviour, energy intake and dietary choices are all factors that can influence body weight in shift workers [96].

The appetite rating increases significantly among night shift workers during the intake of pre-work meals, mainly based on the intake of sweet, starchy foods, vegetables and milk derivatives. During the pre-work meal, overall appetite, food enjoyment and hunger before the meal are also significantly higher among night shift workers. Furthermore, among these workers, changes in caloric intake, the daily distribution of food intake, physical exercise and sleeping habits could explain their weight gain [103].

Eating is a social activity; therefore, the habits of family, friends, and work colleagues will influence a shift worker's eating habits.

It is also important to consider the role that the social context of eating plays in health promotion and obesity prevention. For example, eating in a relaxed environment promotes the activation of anti-stress systems. Thus, it is important to study whether shift work affects the experience of eating and the possibility of eating in a pleasant setting, as well as the tendency to opt for cold food snacks at night, even when hot food is available.

Time availability and social context are important determinants of food intake during work hours, particularly at night. Eating in the workplace is thus influenced by the quality of food and dining facilities that are provided and by the attitude towards food and eating at work. It may be that some workplaces provide only limited menu choices on certain shifts, with the result that energy intake is reduced during that time. It is also important to consider meals eaten outside the workplace.

Night workers commonly experience a mismatch between their own routine and those of their families and friends.

For some shift workers, meal times are a relatively rare opportunity to spend "quality time" with their family. Thus, a night worker might prefer to dine with their

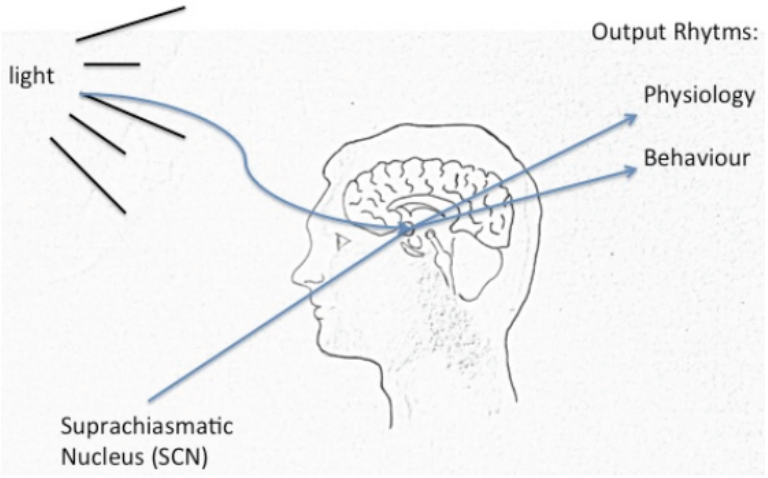


Fig. (4). Schematic outputs due to the light effects on the suprachiasmatic nucleus.

family in the evening before going to work rather than eating a large meal during or after the night shift. Alternatively, they may choose to eat another large meal during the night shift, which could result in overeating. If the night worker does not choose to eat with their family, then it is likely that the meals at home will be self-prepared and eaten alone. As noted above, this may result in the consumption of poorer quality, less healthy meals [96].

4. BIOLOGICAL PATHWAYS

Our biological body clock, located in the suprachiasmatic nucleus (SCN) (Fig. **4**), is stressed by the inversion of the sleep/wake cycle and by modification of the activity/rest pattern producing disturbances in circadian rhythm [104-106].

A transcriptional-translational feedback loop generates the circadian rhythm in the SCN. This rhythm is set to exactly 24 h by environmental stimuli, of which light is the strongest entraining signal in mammals. Other much weaker factors include temperature, fasting/eating, rest/activity, and social cues [69,107].

Obesity of night shift workers is a consequence of insulin resistance, glucose intolerance and sleep disorders produced by melatonin suppression caused by uncoupling of the so-called "oscillators".

These effects are related to continuous light, frequent snacking, nocturnal physical activity, daylight savings time, and shift work [108, 109].

The weight gain of night shift workers is associated with modification of the thermogenic response caused by an irregular food intake pattern [69,110]. One study reported an increase in obesity associated with the duration of the shift [102].

Social and family relationships and food intake patterns of night shift workers are modified by exposure to light when the sun is down.

Several experiences have demonstrated that various chronic diseases are related to poor sleep quality and quantity.

A decrease in the levels of several coronary risk factors, *e.g.*, triglycerides, glucose, and urinary excretion of catecholamines (chemicals such as adrenaline that occur naturally in the body), is associated with the changing of shift rotation schedules [111]. Night shift workers are at risk for vitamin D deficiency due to lower exposure to sunlight [10,112]. Inflammatory diseases of shift workers are associated with their dietary patterns. Western-style diets have been associated with increased chronic, systemic inflammation, whereas Mediterranean diets (*i.e.*, high in fruit and vegetable consumption) have been associated with lower levels of systemic inflammation. Chronic inflammation is an underlying pathophysiological process contributing to the risk of metabolic syndrome, CVD, diabetes, and cancer [98,113,114].

Metabolic responses to food are also altered by shift work-mediated disruptions of sleep and circadian rhythms. These responses include an increase in ghrelin and a decrease in leptin with a deregulation of appetite [103].

Circadian rhythms and sleep/wake homeostasis modulate appetite by causing a disruption of xenin and ghrelin production by means of sympathetic and parasympathetic nervous activity and hypothalamic control of pituitary hormones [109,115].

Laboratory studies have shown that partial sleep deprivation causes changes in two of the hormones in-

volved in the regulation of food intake, ghrelin (a hunger stimulator increased after sleep deprivation) and leptin (an appetite inhibitor decreased after sleep deprivation), prompting an increase in subjective appetite [114,116].

According to a recent study, moderate sleep deprivation leads to an increase in the consumption of energy [117]. Under normal circumstances, leptin levels increase in the late evening, prompting feelings of satiety. Serotonin levels decrease during early-morning hours and prompt feelings of hunger, and its modulation is part of a circadian pattern that promotes nocturnal resting and diurnal eating. This appetite-stimulating profile contributes to the increased fat mass percentage and waist circumference in night workers through a higher intake of total energy, lipids and carbohydrates [118].

An individual's hunger status and the food offered are important factors in the choice of portion size, although regulation of overeating in the morning after a night shift is associated with homeostatic factors [119].

Sleep loss has been linked to increased appetite [120] and enhanced food intake [117,121].

These results demonstrate that the increase of overnight wakefulness, a condition that is typically observed in night shift workers, is associated with feelings of hunger and plasma ghrelin levels. The study shows that night shift workers, compared to workers with normal sleep, selected larger portions of snack foods following sleep deprivation. The portion size decisions after sleep deprivation were associated with the type of food availability and individual hunger status.

Overeating following sleep loss may represent a homeostatic compensatory response. This response was likely produced to compensate for the energy deficit due to sleep deprivation [122].

These results suggest that two independent mechanisms, one homeostatic and one hedonic, may combine to explain the effect of sleep deprivation on hunger and consummatory behaviour [119,123].

Consumption of high-fat snacks, eating meat and eating at fast-food restaurants are the reasons for consuming an unhealthy diet among night shift workers [123]. Many studies have been performed assessing the impact of sleep and circadian disturbance on hormones and metabolism. Shift workers with night work and daytime sleep showed significantly lower melatonin levels compared to daytime workers [124]. The carcinogenic effect of night shift work could be associated with a chronic reduction in melatonin and impaired cortisol secretion.

Prolactin levels were not altered during rotating shift work [125]. Postprandial glucose, insulin, and triacylglycerol responses were significantly greater among night shift workers [126].

Body fat mass, lower insulin sensitivity, increased triglycerides, and blunted post-meal ghrelin suppression and xenin release were higher among night shift workers [114]. Xenin is a peptide secreted predominantly in the upper gut and is known to produce a satiating effect.

Long-term night shift work is also associated with decreased total cortisol [127]. In a study of swing shift workers (1 week of night shift followed by 1 week of day shift), no reductions in reaction times or overall health were observed, but cortisol rhythms did not completely normalize even after 4 weeks of holiday [128]. An experimental rat model showed a disruption of clock and metabolic gene rhythms of animals subjected to 8 hours of "night work" (forced activity during rest and active phases).

PER1, BMAL1, and clock rhythms were inverted: PER2 rhythm was lost in the liver and NAMPT and PPARα genes lost their rhythm and synchrony with clock genes.

These modifications were associated with metabolic syndrome and obesity [129]. Dim Lights at Night (dLAN) and the consequent disruption of circadian rhythms increased body mass, reduced glucose tolerance, disrupted the timing of food intake in mice [91] and reduced the amplitude of PER1 and PER2 rhythms in the hypothalamus [130].

When mice were exposed to chronic jet lag conditions, the expression of Per2 and BMAL1 in the liver was dampened, the tumour suppressor gene p53 expression was suppressed, and the cell cycle progression gene c-Myc expression was induced [131]. Another study revealed that chronic jet lag in mice led to the phase shift of clock genes (Per1, BMAL1, and Per2) and activated expression of p53 and c-Myc in the liver (Fig. **5**) [132]. Food restriction in mice resulted in circadian desynchronization between central and peripheral clocks [133].

Growth hormone, melatonin, cortisol, leptin and ghrelin are affected by sleep quality and circadian rhythms, and numerous clock genes mediate such interactions.

Circadian disruption may negatively affect health due to impaired glucose and lipid homeostasis, reversed melatonin and cortisol rhythms, dysregulation of leptin and ghrelin, more severe metabolic syndrome, and clock gene rhythm loss [134].

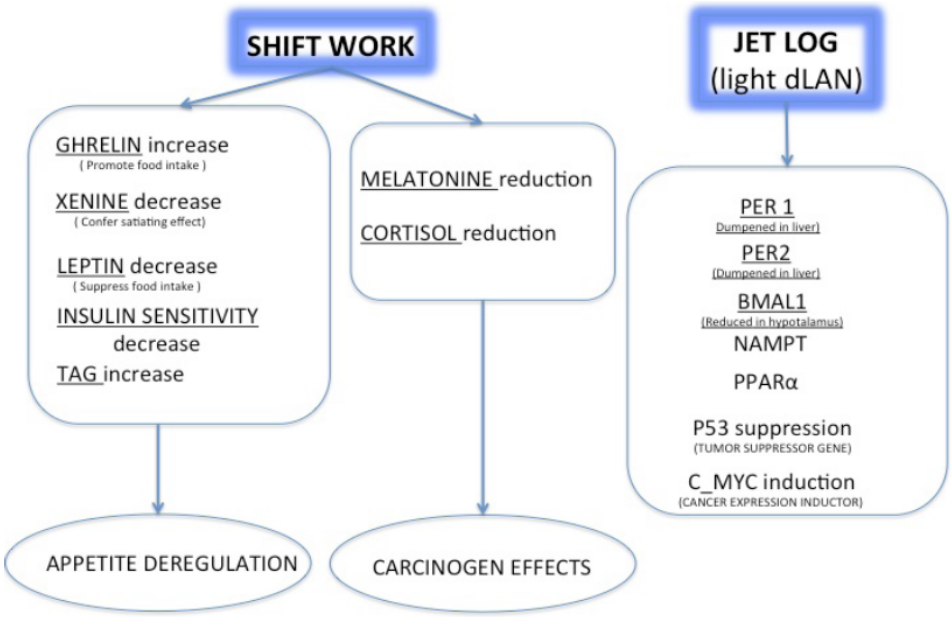


Fig. (5). Hormonal and gene clock modifications due to shift work circadian rhythm disruption.

5. DIET AND EATING PATTERNS IN NIGHT SHIFT WORKERS

As previously indicated, shift work is generally associated with chronic misalignment between the endogenous circadian timing system and behavioural cycles, with adverse metabolic consequences; shifting the time of food intake has been reported to affect postprandial glucose and insulin levels and increase body mass [59]. Recent data show that these shift workers are overweight due to their dietary habits and low physical activity levels, and this is strictly dependent on job-related variables and working time schedules.

These findings suggest a positive role of educational programmes on eating behaviour as a preventive strategy in this group of workers [61]. Shift and night work interferences on health and wellbeing are complex and multifaceted in their origins and time manifestations, dealing with several aspects of personal characteristics as well as working and living conditions. The high price of nutrient-rich, low-energy foods relative to nutrient-poor, energy-dense foods might prevent individuals, especially those who are low-income, from adopting a healthier diet [135,136].

Physical inactivity, unhealthy diets, and obesity are among the top ten risk factors for morbidity and mortality worldwide [135,136].

Interventions to reduce chronic disease risk among shift workers should incorporate several important lifestyle changes (*e.g.*, healthy diet, improved dietary practices, decreased drug and alcohol use, lower levels of drinking and driving, physical activity, proper sleep and light exposure).

Often, shift workers do not practice physical activity and do not consume fruits.

These workers were overweight and most of them did not consume five portions of fruits and vegetables per day. Therefore, health education on these issues is to be implemented [97,137]. A structured intervention can improve the nutritional behaviours of shift workers. This type of intervention enables the workers to be informed and alerted to the risks related to this work schedule and promotes better nutritional behaviours [138]. The points are the absence of social influence on eating (*e.g.*, eating with family) and the 24-hour availability of cheap, tasty and energy-dense food products. When living "around the clock", eating may be promoted, permitted, and facilitated anywhere, at any time. This can encourage snacking or "grazing" behaviour (*i.e.*, eating spontaneously and continuously instead of maintaining a pattern of regular and planned eating events). It is strongly recommended that employers take steps to develop a nutritional management strategy in the workplace. This will involve recognizing that food intake is strongly influenced by motivational factors as well as external factors, such as the availability of foods and beverages and having the time to eat in a relaxing context [96].

To reduce both the health and social costs of the modern 24-hour society, recommendations with regard to meal timing and composition should also consider individual and social barriers [139].

Table 3. Dietetic and organizational guidelines for the prevention of chronic diseases due to shift works.

Maintain regular eating patterns as much as possible.	Balanced, varied meals are very important. Keep family meal times the same even though the work routine constantly changes. Family meals may need to be altered in content to suit the shift worker.
Time meals carefully.	Afternoon workers should have the main meal in the middle of the day instead of the middle of the work shift. Night workers should eat lightly throughout the shift and have a moderate breakfast. This way they should not get too hungry while sleeping during the day and digestive discomfort should be minimal.
Pay careful attention to the type of food eaten.	Drink lots of water and eat the usual balance of vegetables, fruit, lean meat, poultry, fish, dairy products, grains and bread. Eat crackers, nuts and fruit instead of pop and candy bars during work breaks. Reduce the intake of salt, caffeine, and alcohol. Avoid greasy foods, particularly at night.
Avoid excessive use of antacids, tranquilizers and sleeping pills.	It is healthier to watch what and when you eat, and use relaxation techniques to aid sleep.
Relax.	Relax during meals and allow time for digestion.
Restrict energy intake.	Avoid eating, or at least restrict energy intake, between midnight and 06.00 hours, and try to eat at the beginning and end of the shift.
Avoid large meal.	Avoid "large meals" (>20% of daily energy intake) 1–2 hours prior to the main daily sleep episode.
Provide a variety of food choices.	Complete or vegetarian meals and high-quality snacks are recommended.
Avoid low quality snacs.	Avoid foods and beverages classified as low-quality snacks.
Provide appropriate dining facilities.	For example, allow a meal to be eaten away from the workplace, with colleagues, in as pleasant a surrounding as possible.
Maintain a healthy lifestyle	Exercise, regular meal times, and good sleep hygiene when not working.
Avoid wakening due to hunger.	Eat breakfast before day sleep.
Divide the energy 24-hour intake.	Divide into eating events with three satiating meals each contributing 20–35% of 24-hour intakes. The higher the energy needs, the more frequent the eating should be.
Avoid high energy foods.	Avoid over-reliance on (high-energy content) convenience foods and high-carbohydrate foods during the shift
Choose quality foods.	Choose vegetable soups, salads, fruit salads, yoghurt, wholegrain sandwiches, cheese or cottage cheese (topped with slices of fruits), boiled egg, nuts, and green tea (promoting antioxidant activity), although this may not be palatable to some.
Design proper shift schedules.	To allow adequate time between shifts for sleep, meal preparation, amongst others, avoid quick returns.

(Source: Lowden, A.; Moreno, C.; Holmbäck, U.; Lennernäs, M.; Tucker, P. Eating and shift work - effects on habits, metabolism and performance. Scand J Work Environ Health, 2010, 36(2), 150-62.)

Shift workers often change their food intake patterns, resulting in health damage in ways that may be unfavourable to health. However, this risk can be prevented by using appropriate interventions such as nutritional education programmes.

Regarding nutritional strategies for shift workers, it seems that in addition to general guidelines, we need more practical and specialized recommendations to meet the workers' nutritional requirements in different settings with various conditions [97]. It is necessary to identify a set of dietary guidelines (Table **3**; Table **4**) that may help to minimize the health problems experienced by shift workers. The term "eating behaviour" will be used to encompass the following dimensions of the dietary assessment: (i) the timing and frequency of eating; (ii) meal composition; (iii) food composition; and (iv) the habitual average intake of energy and essential non-energy yielding nutrients (*e.g.*, vitamins, minerals, fatty and amino acids, and bioactive components that cannot be synthesized within the body) [96].

In the workplace, strategies employed to promote healthy eating to date have largely focused on individual responsibility (education and behaviour change). Some programmes have implemented changes in worksite environments in order to make healthy choices easier, but these have largely focused on changing the physical environment [97, 140]. With regard to the benefits of workplace health/nutrition promotion programmes, employers are keenly interested in programmes and policies that improve workers' health and ultimately reduce healthcare costs [141].

Table 4. Scientific guidelines for shift organization.

Rotation speed.	Quickly rotating shift systems are better than slowly rotating ones.
Rotation direction.	Clockwise rotation (morning/afternoon/night) is preferable to counter-clockwise (afternoon/morning/night).
Working starts.	Avoid early starts for the morning shift.
Prolonged work.	Prolonged work shifts (9–12 hour) should only be considered when the workload is suitable, there are adequate breaks, and the shift system is designed to minimize accumulation of fatigue and exposure to toxic substances
Work regularity.	Shift systems should be regular and able to guarantee as many free weekends as possible.
Permanent night work.	Permanent night work can be acceptable only for particular working situations which require a complete adjustment to night work to guarantee the highest levels of safety. Be aware that such complete adjustment requires people to maintain the inverted sleep/wake cycle also on rest days and to avoid exposure to bright light after night shifts (*i.e.* wearing dark sun glasses while commuting home).
Time off between shifts.	Adequate time off between shifts should be allowed to compensate for fatigue and sleep as quickly as possible (*i.e.* two shifts in the same day must be avoided), and rest days should come preferably after the night duty period to allow prompt recovery from sleep deficit and an easier return to the normal sleep/wake cycle.
Flexibility.	Some flexibility in working times is desirable to give the workers the possibility of combining better work duties with family and social life.

(Source: IARC 2010; Costa 2010; Kuanth 2003).

Since individuals spend more than 50% of their waking hours in their place of work, worksite interventions may improve dietary habits and promote weight loss and psycho-physical wellbeing.

Thus, having catering services in worksites may be associated with healthier eating habits. For example, shift workers consumed fewer vegetables, which may reflect the unavailability of proper meals [101]. Considering that metabolic disease is associated with circadian disruption in humans [142,143] and that the clock uses nutrient input to set the local time, it is conceivable that both the timing and nutrient composition of one's diet might be key components of personalized medicine in the future, in parallel to individual behavioural and genetic predisposition [89]. Currently, practical applications for the general public are being developed based on decades of research on the internal clock and its molecular underpinnings. For example, the Entrain app was developed based on the heavy dependence of our internal clock on the light/dark cycle. This app was designed to assist with optimal circadian re-entrainment to a new light/dark cycle using mathematical models based on and incorporating thousands of different circadian misalignment possibilities [144]. Recently, new proposals have been made: an Ecological Momentary Intervention for weight loss and healthy eating *via* a smartphone and the internet [145], a lifestyle intervention programme including dietary counselling, advice on increasing physical activity, and recommendations to stop or limit smoking and alcohol intake.

Nutrition has also been proposed as a powerful re-entrainment mechanism to circadian misalignment based on the repeated demonstrations of its effectiveness in controlling the peripheral circadian rhythm. Based on the number of potential zeitgebers that arise from different nutritional inputs, it may be that food intake and chronotype will jointly play prominent roles in the future of personalized medicine [89].

Health surveillance protocols are important for shift workers' wellbeing, and they should be based on basic anamnestic physiological, pathological and job data collection.

We have to understand the best coping strategies to prevent disorders related to shift work and limit them, particularly with reference to sleep habits, diet, physical fitness, and leisure times [9].

CONCLUSION

Interventions to reduce chronic disease risk among shift workers should incorporate several important lifestyle changes (*i.e.*, healthy diet, improved dietary practices, decreased drug and alcohol use, physical activity, proper sleep and light exposure).

The reported findings suggest a possible role of education programmes on eating behaviour as preventive strategies in this group of workers.

The generic relationship between diet and the prevention of diseases in shift workers was the object of several studies. However, what is actually missing is a deep knowledge of the relationship between specific dietary compositions (*i.e.*, a Mediterranean diet) and

prevention programmes for diseases among shift workers. The next step in our research is to plan a large meta-analysis to assess specific pooled estimates adjusted by publication bias and with a reduced variability.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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