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Exercise, Energy Balance and the Shift Worker

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Abstract

Shift work is now common in society and is not restricted to heavy industry or emergency services, but is increasingly found amongst 'white collar' occupations and the growing number of service industries. Participation in shift work is associated with increased body mass index, prevalence of obesity and other health problems. We review the behavioural and biological disturbances that occur during shift work and discuss their impact on leisure-time physical activity and energy balance.

Shift work generally decreases opportunities for physical activity and participation in sports. For those shift workers who are able to exercise, subjective and biological responses can be altered if the exercise is taken at unusual times of day and/or if the shift worker is sleep-deprived. These altered responses may in turn impact on the longer-term adherence to an exercise programme. The favourable effects of exercise on body mass control and sleep quality have not been confirmed in shift workers. Similarly, recent reports of relationships between sleep duration and obesity have not been examined in a shift work context. There is no evidence that exercise can mediate certain circadian rhythm characteristics (e.g. amplitude or timing) for improved tolerance to shift work.

Total energy intake and meal composition do not seem to be affected by participation in shift work. Meal frequency is generally reduced but snacking is increased on the night shift. Unavailability of preferred foods in the workplace, a lack of time, and a reduced desire to eat at night explain these findings. 'Normal' eating habits with the family are also disrupted. The metabolic responses to food are also altered by shift work-mediated disruptions to sleep and circadian rhythms. Whether any interactions on human metabolism exist between timing or content of food intake and physical activity during shift work is not known at present.

There are very few randomised controlled studies on the efficacy of physical activity or dietary interventions during shift work. Some favourable effects of such interventions on fatigue levels at work have been reported, but biological and behavioural outcomes relevant to long-term health and energy balance have not been studied adequately. In addition, recruitment and retention of research participants for randomised controlled trials of physical activity or dietary interventions has been very difficult. We present a model of the various behavioural and biological factors relevant to exercise and energy balance during shift work as a framework for future research.

Keywords

Night work; Obesity; Physical activity; Eating habits; Circadian rhythms

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1. Introduction

For many years, shift work has been required to provide vital services and emergency cover at all hours of the day and night, as well as for maintaining long-term industrial processes. Nevertheless, shift work is no longer restricted to these types of occupations, but is increasingly found in modern 'call centres', where employees deliver financial and retail services around the clock as well in supermarkets, newsrooms and banks. It is not surprising, therefore, that 13–20% of workers in Europe and the United States are now involved in a shift work schedule that includes some time spent working at night.[1] Many employees can also be found working at what can be described as 'unusual hours'; outside of the 'normal' 9am–5pm period, but not necessarily involving night work, *e.g.* the permanent early morning shifts worked by postal delivery personnel or the shorter morning and evening 'split-shifts' worked by public transport staff or office cleaners.

Shift work schedules differ markedly in terms of the timing and duration of each shift as well as the speed of shift rotation. Nevertheless, it is generally accepted that long-term participation in most shift work schedules is associated with health problems compared to day workers [1,2]. Shift workers have been found to be at increased risks of insomnias, chronic fatigue, anxiety and depression, adverse cardiovascular and gastrointestinal effects, as well as some aspects of impaired reproduction in women. [1,2] Most relevant to the present review, the results of several well-controlled (for potential confounders) epidemiological studies suggest that exposure to shift work is an independent predictor of increased body mass[3] body mass index [4,5] prevalence of obesity [6-8] and waist-to-hip ratio [9].

Various interactions between the influence of shift work on indicators of obesity and age, gender and type of shift worked have been reported by some of the above researchers [10]. The presence of these interactions suggests that the exact explanation for the detrimental effects of shift work on health is complicated. Possible biological and behavioural reasons for the health problems of the shift worker are discussed in most general reviews, and a few authors have mentioned, albeit briefly, the possible impact of poor energy balance on these problems. For example, Harrington [1] identified improvements in catering and recreational facilities as factors which can ameliorate shift work problems in the short-term. Harrington [1] also mentioned the importance of physical fitness and physical activity in helping workers reduce the problems associated with shift work. Nevertheless, the complicated relationships between all the various biological and behavioural factors that influence energy balance during shift work have not yet been summarised in a review article dedicated to this area.

The World Health organisation defines 'health' as the *"state of complete physical, emotional and social wellbeing, not merely the absence of disease or infirmity."* [11]. A consideration of the health and energy balance of the shift worker needs to encompass these physiological, psychological and sociological dimensions of health. For example, shift work may influence the nutritional health of an individual by affecting individuals' eating behaviour whilst at work, through the disturbance of sleep patterns and circadian rhythms in metabolic responses to food, and/or by interacting with the social and family influences on eating habits when not at work.

In view of all the factors which can influence the health of the shift worker, only a multi-level [12] summary of the evidence has the potential to unravel the influence of these factors, and this approach has not yet been attempted in the area of energy expenditure and energy intake of shift workers. There has been no focussed attempt to analyse the current knowledge on the influence of timings of meals and physical activity on the problems

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associated with shift work and it is unclear whether these problems are due to disturbance of the circadian rhythm (the “body clock”) and/or a decreased opportunity to adopt the desired timing of lifestyle and social habits.

2. Problems with energy intake

It is commonly found that gastrointestinal complaints are more prevalent among rotating and night shift workers compared to day workers [13]. These complaints include: disturbances of appetite; irregularity of bowel movements; constipation; dyspepsia; heartburn; abdominal pains; grumbling and flatulence. It has been stated that between 20–75% of shift workers, compared to 10–25% of day workers, report such complaints [14]. There are wide ranges in the reported prevalence rates of these symptoms, particularly amongst shift workers. Between-study heterogeneity is also the case when the prevalence of peptic ulcers amongst shift workers is considered. For example, Segawa *et al.* [15] found that the prevalence of gastric ulcers was 2.4% in current shift workers compared with 1.0% in day workers. Nevertheless, Costa [16] reported that the prevalence of peptic ulcers could be eight times greater for shift workers compared to day workers. These differences in prevalence rates may be due to variability in the nature of the clinical examination employed as well as the quality of interview data collected from the shift workers. Notwithstanding these inter-study differences in magnitude of event rates, the fact remains that gastro-intestinal problems, which could obviously impinge on ‘normal’ eating habits, are more common in shift workers.

There are reports of altered lipid profiles in shift workers, [17-19] although the results of these studies are not completely consistent in terms of which specific lipid concentrations are altered. Romon, *et al.* [18] found that shift workers had higher levels of serum triglycerides compared to day workers (1.26 vs 1.03 mmol/l), but levels of cholesterol and high density lipoprotein cholesterol (HDL) were similar between the two groups as well as comparable to normal population reference ranges. Karlsson *et al.* [7] found a high concentration of triglycerides (>1.7 mmol/l), but low concentrations of HDL (<1.0 mmol/l), in a shift working population. Ghiasvand, *et al.* [19] reported that cases of high concentrations of serum total cholesterol (>5.13 mmol/l) and low-density lipoprotein cholesterol (>3.33 mmol/l) were both more common amongst shift workers. The latter finding is supported by the results of Knutson *et al.* [17] who found that the ratio between Aplolipoprotein B and Aplipoprotein A increased during shift work. Apolipoprotein A is the main protein component of HDL and promotes the transfer of cholesterol into the liver, where it is metabolized and then excreted from the body via the intestine.

In analysing the causes of the above epidemiological observations, it is clear that a shift worker may be restricted behaviourally, in terms of the desired amount and type of food that is eaten during working hours, and because traditional meal times in the home are disrupted. In addition, there may be a biological disruption to circadian rhythms relevant to the metabolism of food eaten during shift work. Both these behavioural and biological factors, which might combine to lead to unhealthy consequences, will now be considered in detail.

2.1. Eating behaviours of shift workers

In order to gain comprehensive knowledge about the eating behaviour of shift workers, past researchers have measured overall energy intake and macronutrient composition over 24 hours, the prevalence of snacking during different shifts, the number of meals consumed, and the timing of these meals and snacks. It appears from the results of these dietary surveys that the timing of meals, rather than their overall content, is affected most by shift work. Lennernas *et al.* [20] used a repeated 24-h recall strategy that was administered to shift workers over 5 days of a rotating three-shift system (morning, afternoons, nights). The total

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amount of food ingested over a 24-h period did not differ between the three shifts. Nevertheless, when data were analysed over individual 8-hour work periods, food intake was higher on the morning shift than during the evening shift. This observation may be mediated by circadian factors related to appetite or by a decreased availability of meals during the night shift. Lennernas *et al.* [21] also compared workers on 3-shift and 2-shift schedules to day workers across a complete work cycle. No differences were found with respect to total energy intake or dietary composition (calculated as % energy from protein, fat, total carbohydrates and sucrose) as well as intake of vitamins and minerals).

In contrast to the findings of Lennernas *et al.* [20, 21], Sudo & Ohtsuka [22] found that total energy intake of Japanese female shift workers was 200–400 kcal/day less than that of day workers. Shift workers ingested less protein, fat and carbohydrate. The authors attributed these differences to a lower meal frequency and poorer quality of meals on the night shift. Takagi [23] also showed that shift work led to a reduction in the number of meals eaten on the evening and night shifts, while workers on the day shift adhered to the more traditional three-meals-per-day. The apparent disagreement in research findings between Japanese and Scandinavian studies may be due, in part, to differences in data collection methods and analysis, making comparisons between studies tentative at best. At present there is no section devoted specifically to eating habits within the commonly used data collection tool, the Standard Shiftwork Index [24]. Such a section in this Index would be informative, but has not been included before, probably because of concerns about lengthening an already comprehensive suite of questionnaires.

Shift work may also increase ‘snacking’ of energy-dense foods, depending on the shift that is worked. De Assis *et al.* [25] found no significant difference in total food intake between morning, afternoon and night shift workers; nevertheless, morning shift workers ingested more energy and macronutrients in the morning than the other shift workers (Figure 1). Afternoon and night shift workers had a greater energy intake at noon and at dawn, respectively, than morning shift workers. Night shift workers, like morning shift workers, consumed high-energy foods and drinks, high energy being obtained from carbohydrates, during their work shifts, rather than during the afternoon. It can be concluded from these data that, while total energy intake and composition is little affected by shift working over a 24 hr period, meal frequency is reduced but the prevalence of high-energy snacking is increased on the particular shift that is worked [25, 26, 27].

Important factors which impinge on the dietary habits of the shift worker are the specific type of job, the work environment and the availability of food in the work place. Fisher *et al.* [28] reported a significant influence of working arrangements and sleeping habits on meal times. Availability influenced most types of foods consumed. Other researchers have also found that work schedules have a greater influence than feelings of hunger in determining the timing and type of food intake [29] (Table 1). Stewart & Wahiqvist. [30] studied workers in the steel and aluminium industry and found inadequate canteen facilities, resulting in a greater reliance on vending machines. Shift workers who regularly brought food in to work generally consumed more lower-energy dense food items (defined as those containing < 1642 kJ or < 17 g of fat) than those using canteen facilities. On the night shift, workers were more likely to consume more items of higher-energy dense food than those on afternoon or morning shifts, and this also coincided with higher usage of vending machine facilities.

The decisions surrounding the diet of shift workers are obviously influenced by external factors such as work schedules and availability of food. However it is also important to consider the impact of shift work on dietary habits from a socio-behavioural perspective. Persson & Martensson [31] used a critical-incident approach to explore nurses’ dietary habits, and found that this group of workers was influenced particularly by social

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interactions and by the disruption to their circadian rhythms. For example, the nurses often chose 'healthy' foods to help alleviate some of the gastrointestinal symptoms they experienced during the night shift. Other reasons for food choices included using high-sugar foods to help overcome tiredness and cravings whilst working on shifts.

Shift work may also disrupt the normal diurnal pattern of social and family life. This disruption may be particularly significant for females with children. These workers often exhibit a clear increase in the off-job workload, caused by domestic duties [32]. Some of these duties may include the preparation of food for family mealtimes, which cannot be rescheduled to suit the shift worker and may be at odds with an individual's sleep pattern or appetite. Indeed, it is these types of problem that should be considered when establishing key interventions to help improve the nutritional health of shift workers. In order to be successful in reducing both the health and social costs of the modern 24-hour society, recommendations with regard to meal timings and composition, aimed at alleviating the negative health consequences of shift work schedules, should also take into account individual and social barriers.

2.2. Biological disturbances associated with eating during shift work

It is important to consider how the altered eating behaviours of shift work impact on metabolic and endocrine responses, and other nutritional health parameters which are of particular importance in the development of disease. From a circadian point of view, the body is not designed for a nocturnal intake of energy and nutrients. Glucose tolerance decreases from morning to night and nocturnal eating increases the LDL/HDL cholesterol ratio, [33] which is a cardiovascular risk factor. Plasma triacylglycerol, the major lipid component of dietary fat, also appears to be influenced by the circadian clock, with higher levels observed during the night [34]. Nocturnal eating has been shown to cause an increased triacylglycerol response after a nocturnal meal compared to one eaten during the day. Morgan *et al.* [35] administered a constant routine protocol to participants and reported that the concentration of plasma triacylglycerol increased by 0.2 mmol/l at night. It was postulated that such an increase might be due to the decrease in nocturnal insulin sensitivity that was also observed by these researchers. Insulin is an important activator of lipoprotein lipase, the key regulatory enzyme involved in triacylglycerol clearance and hence a reduction in sensitivity may result in a similar reduction in lipoprotein lipase activity. This notion is supported by the results of a later study on permanent night shift workers in Antarctica. Test meals were used to determine postprandial hormone and metabolic responses during the daytime, at night and at the beginning of a night shift. The lack of adjustment of circadian rhythms to the night shift was associated with increased insulin resistance and lipid intolerance [36]. The hypothesis that reduced insulin sensitivity may be a factor in reducing triacylglycerol clearance during the night is also supported by more recent work [37]. Similarly, further evidence that shift work is associated with elevated lipid levels has been presented by past researchers [3] and in more recent studies [19, 38].

While reduced insulin sensitivity may mediate a reduction in triacylglycerol clearance, it is also a risk factor itself in the development of diabetes. At night, there is a reduced glucose utilisation, lowered insulin secretion rates and a reduction in insulin sensitivity [37, 39, 40, 41]. The fall in glucose utilisation during early sleep is due to a decrease in brain glucose metabolism during slow wave sleep (which is concentrated into the first part of sleep) as well as reduced muscle tone and the anti-insulin effects of growth hormone [42]. This finding has implications for shift workers who eat during the night, since it is known that there is less insulin secretion for a given glucose stimulus in the night compared to the daytime [43]. Sleep deprivation itself may also cause decreased insulin sensitivity. Spiegel *et al.* [42] found that the peak glucose response during the few hours after breakfast was higher by 15 mg/dl during six 24-h periods of restricted (4 h) sleep compared to a period of normal sleep.

Gastrointestinal activity may also be disturbed as a result of nocturnal eating. There is a reduction in gastric emptying time at night [44] and a reduction in pancreatic polypeptide, which is an indicator of gastrointestinal tract activity [45]. Hirota *et al.* [46] found that exposure to bright light in the evening reduced the absorption of dietary carbohydrate. These last findings suggest that entrainment signals such as the light-dark cycle, which have an altered timing relative to the body clock during shift work, may affect metabolism of food. Such a hypothesis has not been formally tested to date.

It is also relevant to consider the impact of shift work on endocrine function, especially those hormones involved in energy balance. The adipocyte-derived hormone, leptin, tends to inhibit food intake, whereas ghrelin tends to stimulate it [47]. Leptin and ghrelin secretions may be related to the sleep-wake cycle and exhibit a circadian rhythm. Both sleep deprivation and shifts in the timing of the sleep period alter plasma concentrations of these hormones [48, 49]. Some authors have suggested that mealtimes influence leptin levels to a greater degree than ghrelin. Fogteloo *et al.* [50] showed that changing meal frequency from 3 to 8 times per day influenced the 24-hour rhythm in leptin. Schoeller *et al.* [51] also observed phase shifts in plasma leptin levels as a result of changing meal patterns. In an investigation more relevant to shift work, Qin *et al.* [39] studied the effects of a nocturnal lifestyle on serum leptin. Night-time consumption patterns chosen for this experiment were similar to those observed in shift workers. Participants consumed more than 50% of their total energy intake in the evening and night, with a greater frequency of eating but less food eaten at each time. This pattern of eating was thought to have resulted in an inadequate suppression of appetite, as evidenced by the decrease in the nocturnal peak of plasma leptin levels.

2.3. Dietary interventions during shift work

In a report by the World Health Organisation, the links between diet and nutrition on chronic diseases such as obesity, type 2 diabetes, cardiovascular disease, cancer, dental disease and osteoporosis were highlighted. It was proposed that nutrition ‘should be placed at the forefront of public health policies and programmes’ [52]. There is a clearly-established link between inadequate diet and the development of disease for people living a ‘normal’ diurnal existence. Given the altered eating habits as well as metabolic and endocrine profiles of shift workers outlined in the previous section, it seems even more important to provide evidence-based nutritional recommendations for this population. While there are a number of studies relevant to the effects of shift work on dietary habits and intake, few researchers have been able to formulate evidence-based recommendations for shift workers. The formulation of any recommendations should be based on knowledge about the metabolic consequences of shift work as well as tolerance to shift work at the individual and socio-behavioural levels.

In one of the few studies that we could locate, Love *et al.* [53] investigated the effects of altering meal composition on subjective alertness scores during shift work. These scores improved significantly with a test meal of 46% carbohydrate and 42% fat during a night shift, compared with a ‘baseline’ meal (56% carbohydrate; 28% fat). These findings concur with those from studies on cognitive performance during the daytime. Nevertheless, the long-term consequences of raising the amount of dietary fat whilst working shifts are still unknown. Again, there is a need for more multi-disciplinary research (involving shorter-term and longer-term outcome variables) on nutrition during shift work.

Future researchers should also address the fact that shift work and night work impose a fundamental clash with normal diurnal existence. It is not possible or practical for many

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shift workers and night workers to adjust their circadian rhythms or lifestyles sufficiently to be able to synchronise with such an altered existence, especially when working rapidly-rotating shift systems.

3. Problems with energy expenditure

In parallel with the above considerations surrounding dietary factors, shift work might also interfere, behaviourally, with the opportunities to perform physical activity and, biologically, with the normal responses to a bout of physical activity. These different responses to exercise might alter the mechanisms of energy balance (e.g. a change in the relative use of energy substrates during exercise) and/or affect how well tolerated is exercise at a paricular time of day (e.g. through a change in perceived exertion during exercise). The latter issue might have implications for the long-term adherence to physical activity regimens during shift work.

3.1. Physical activity behaviours during shift work

Shift work obviously leads to added difficulties in fulfilling domestic and family responsibilities, and the exact impact of shift work on such roles has been researched empirically. It is likely that most immediate family members alter their behaviour when a shift worker is present in that family. Partners and children will, for example, attempt to be quieter while the shift worker is trying to sleep during the day. Shift work might also restrict participation in social and leisure activities. This disruption might be different from that of the domestic situation, since leisure activities and sports clubs are generally scheduled to accommodate those with relatively ‘fixed’ diurnal existences, and there is little scope for adapting arrangements for the demands of a specific shift worker [54-57]. Nevertheless, the discrepancy between the desire of a shift worker to participate in leisure and sports activities and the availability of these leisure opportunities probably depends on the specific type of interest (team or individual-based, organised or self-motivated).

Leisure activities during team sports, group activities or organised events are often inflexible and do not meet the needs of shift workers. This conflict either results in the worker not participating in that particular activity or contributes to the decision to leave shift work altogether [58-62]. Lipovcan *et al.* [54] reported that night workers had problems maintaining physical fitness compared to other groups of workers. Whilst the night workers who were studied understood the importance of habitual physical activity, there were problems with the implementation and maintenance of an active lifestyle. A lack of time and opportunity for exercise have been cited, alongside increased general fatigue, as reasons for a less active lifestyle. For those shift workers who enjoy solitary or individual activities, the disruptive nature of shift work might be less of a concern. For example, it is possible that shift workers who join fitness and health clubs enjoy the benefits of ‘off peak’ membership rates and utilise the facilities at the quietest times, so avoiding the crowds who use the facilities at peak periods. Atkinson and Reilly [63] reported that 12% of a sample of older racing cyclists was involved in nocturnal shift work. This proportion of shift workers is similar to that in the UK population as a whole. Cycling is one sport, swimming and jogging are others, which can be carried out on an individual basis. Indeed, shift workers might actually be at an advantage compared to day workers in that they are able to train more frequently in the daylight hours, especially in the winter months. Nevertheless, participation in organised individual competitions may still be hindered by shift work, since it is more likely that a rotating shift worker is required to work on weekends.

Another important factor for short- and long-term maintenance of physical activity is whether the psycho-physiological responses to exercise are altered during shift work. Even though a shift worker might not have reduced opportunity to participate in some activities,

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increased fatigue and the negative experiences of exercising at a time that is out of kilter with the ‘body clock’ during a shift work schedule might be significant enough to stop the activity. A deciding factor for the shift worker may be whether any exercise exacerbates or improves the existing difficulties each individual shift worker experiences. Therefore, it is relevant to consider whether the responses to exercise are altered during shift work

3.2. Biological factors associated with physical activity during shift work

One factor which complicates the interpretation of the benefits of exercise is that it is possible that participation in leisure-time physical activity is more amenable to those individuals who are generally more tolerant to shift work. Besides this ‘chicken and the egg” problem, general tolerance to shift work does vary considerably between individuals [2, 64, 65]. Some individuals might exhibit severe indications of intolerance even within a few weeks of starting shift work, whilst it may take many years for other individuals eventually to leave shift work because they just cannot tolerate the difficulties anymore. The reasons for these large individual differences are difficult to pinpoint from a chronobiological perspective. It has been postulated that higher amplitudes of circadian rhythms result in a greater ‘stability’, which could be advantageous for coping with recurrent rhythm disturbances (although this, again, would depend on type of shift system) [66, 67]. A number of researchers have reported that the rhythm amplitudes of physically fit or physically active subjects are higher than those observed in unfit or inactive subjects [67-69], but such descriptive relationships are fraught with confounders and difficulties in interpretation. It is unclear whether such higher rhythm amplitudes are mediated by the physiological adaptation that occurs with improved fitness or whether habitual physical activity acts as a ‘synchroniser’, mediating a ‘stronger’ observed rhythm. Moreover, a positive association between circadian rhythm amplitude and shiftwork tolerance has not been confirmed by several researchers [66, 70]. Interpretation of this relationship is fraught with difficulties, since it is possible that a shift worker has a high amplitude circadian rhythm as a consequence, not as a result, of being more able to tolerate disturbances in the sleep-wake cycle. In the context of physical activity, it may be that the workers who generally cope well with shifts might be more inclined to exercise than those who do not cope with shifts so well. This exercise could mask the endogenous circadian rhythm in that it would amplify the exogenous effect of the sleep-wake cycle on a measured rhythm. This ‘self-selection’ effect is a problem in most shift work research, especially for studies on the influence of ageing on tolerance to shift work.

Physical activity may be beneficial to the shift worker by generally improving sleep quality [65, 71, 72]. Unfortunately, there is a lack of information regarding the precise mechanisms underpinning the association between physical activity and its hypothesised sleep-promoting effects, even for non-shift workers. Nevertheless, it is known that habitual bouts of physical activity increase both the duration (possibly as a result of decreasing sleep latency) and quality of nocturnal sleep. The amount of slow wave sleep (SWS), which is thought to be important for brain restoration and recovery during nocturnal sleep, is also increased by physical activity [71].

Youngstedt [71] discussed the various hypotheses regarding how physical activity improves nocturnal sleep quality. It is possible that physical activity is beneficial via a reduction of anxiety, a sleep-inducing thermogenic effect, long-term antidepressant effects, or by leading to a more favourable circadian phase for sleep. Horne and colleagues [73, 74] suggested that increases in sleep quality following exercise were mediated by temperature elevation which, in turn, increased SWS. Murphy and Campbell [75] found that chronic physical activity promotes the sleep-onset process by promoting more proficient temperature down-regulation, which is generally thought to promote sleep. Attenuated temperatures at night have been found in people with depression, sleep disruptions, and insomniacs. Such

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attenuations could be reversed with the successful use of chronic physical activity as a treatment [71]. With this in mind, disruptions to the sleep-wake cycle and subsequent disturbances on sleep quality and quantity as a direct result of shift work could plausibly be alleviated or attenuated by the administration of a successful physical activity intervention. A physical activity intervention could conceivably increase sleep quality in shift workers as a result of the thermogenic effects, a reduction in anxiety and depression, or via circadian phase-shifting. Yet research in the field of physical activity, sleep and shift work is surprisingly scarce. Thus, the suggested benefits that habitual physical activity could have on the sleep quality and quantity of shift workers are still highly speculative.

Intuitively, one would think that physical activity (especially exercise of a high intensity) performed in the late evening would have an adverse effect on subsequent nocturnal sleep. The optimal temporal positioning of physical activity is thought to be between 4–8 hours before a normal nocturnal bedtime (for day workers) [65]. Nevertheless, it is difficult to extrapolate such findings to shift workers, who commonly cite the need to catch up on sleep as a fundamental barrier to participating in leisure time exercise. Shift workers who are motivated enough to exercise might find themselves engaging in activities outside of a normal diurnal existence, such as exercising directly before/after a sleep period or late at night [1, 16, 56, 61]. The exact consequences of these unusual timings of exercise bouts relative to (the unusual timings of) sleep periods are not known. Interestingly, it seems from one investigation that the negative effects of exercise when taken close to the start of a sleep period may have been overestimated, [76] although this new evidence is again based only on exercise prior to nocturnal sleep in people living diurnally.

There is evidence that the temporal placement of physical activity can also affect the adjustment to shift or night work via advancing or delaying an individual’s circadian rhythms [77]. If, via appropriately timed exercise, circadian rhythms can be adjusted to times more amenable to the particular shift that is being worked, it is possible that feelings of fatigue, tiredness, sleepiness and other short-term effects of working unusual hours may be attenuated. These improvements in shorter-term tolerance might, in turn, make exercise more tolerable to the shift worker and so aid maintenance of participation in physical activity regimens. Atkinson & Davenne [77] recently reviewed the literature on whether exercise is a synchroniser of human circadian rhythms. In such studies, there have been difficulties in controlling the characteristics of the exercise bout, the athletic status of research participants, and exposure to other confounding synchronisers. Nevertheless, it is clear that nocturnal exercise can induce phase delays in the onset of melatonin secretion. Reports of exercise-induced phase advances of the melatonin rhythm are rarer, as were any phase-shifting effects at all on the body temperature rhythm. Importantly, the substantial levels of activity (possibly 3 h of exercise at 50–60% of maximal oxygen uptake) needed to obtain phase shifts are impracticable and may even be unattainable by the majority of shift workers.

Associations have been found between habitual physical activity and the alleviation of some clinical sleep disturbances. The results of one large epidemiologic study (n=1104) suggested that the number of hours of exercise per week was inversely related with the severity of sleep apnea [78]. The results of recent studies also suggest that short-sleep duration is associated with obesity [79, 80]. Individuals who frequently work irregular schedules or participate in rapidly-rotating shift work suffer from repeated disturbances of their sleep-wake cycle, which can lead to chronic sleep deprivation [79, 81]. It is well known that sedentary habits have been associated with a high prevalence of obesity and shift workers might be more sedentary than day workers. Nevertheless, all these relationships between physical activity, sleep duration and obesity have not been explored amongst shift workers.

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3.3. Physical activity interventions during shift work

It is well documented that a better general health of a workforce is related to lower labour costs, higher productivity and lower rates of employee absenteeism or resignation [82-85]. Worksites may offer unique opportunities to encourage employees and their families to engage in physical activity. During the last 20 years, researchers have explored the efficacy of a variety of worksite-based physical activity interventions, ranging from 20 min of extremely vigorous exercise performed three times a week, to the more moderate physical activity associated with fitness classes and group activities [86, 87]. After he reviewed the literature, Shephard [88] found that worksite-based physical activity interventions decreased body mass by 1–2%, decreased blood pressure by between 2–10 mmHg and decreased serum cholesterol by 15%, on average. Shephard [88] also reported a reduction, albeit a small one, in absenteeism as well as an average increase in productivity of 4–5%.

In view of the general benefits of worksite-based physical activity interventions, it is surprising that physical activity, fitness and energy expenditure during shift work have received very little attention. It has been postulated that those shift workers who adopt active/engaging coping mechanisms, including habitual involvement in physical activity, are better able to tolerate the stresses and strains of shift work and are generally healthier [54, 59, 65, 89, 90]. There is some epidemiological support for these postulations. For example, Kivimaki [90] found relationships between the prevalence of being overweight, sedentary behaviour and age amongst 506 shift workers. Such descriptive data have led some authors to speculate that interventions surrounding physical activity might be useful to the shift worker. For example, Harrington [1] speculated that improved recreational facilities to promote active living might be useful for general tolerance to shift work. Nevertheless, there is little empirical support for such views.

To date, there has been only one study involving a physical training intervention designed specifically for shift workers. Harma *et al.* [68, 89] designed a training programme for 119 female shift workers. Exercise sessions were administered between 2 and 6 times per week, between 60–70% of maximal heart rate, and for a 4-month period. Harma *et al.* [68, 89] found that this moderate physical training mostly benefited aspects of sleep. The mean sleep length of the training group increased after the evening shift by 4.9%, significantly greater than the control (no exercise) group. General fatigue decreased significantly in the training group during the whole cycle of rotating shift work, and scores on some tests of performance improved. The authors suggested that moderate exercise should be performed several hours before the main sleep period when on a morning or day-shift schedule. During a period of night work, physical activity was advised before an evening nap, although the researchers did not investigate these specific issues about the timing of exercise.

It should be noted that the changes in body mass and body composition in the studies of Harma et al. [66, 89] were not different from those of the sedentary control group (Table 2). It can also be seen in Figure 2 that exercise training was associated with a slight decrease in alertness on the evening shift compared to a slight increase in evening shift alertness with control subjects. Although these findings could have been due to pre-existing differences between experimental groups at baseline, they do raise questions surrounding the efficacy of acute and chronic effects of a bout of exercise during shift work. In addition, 'nervous symptoms' did not decrease as expected following the exercise intervention. Harma *et al.* [68, 89] postulated that an increased participation in physical activity at the expense of spending leisure time with the family might have increased stress more so than the attenuation produced by the physical activity per se. This finding illustrates how any lifestyle change must be considered also in the context of its implications for the family, close friends and social contacts. Future interventions of this nature might also indirectly deal with the issues surrounding 'lack of time', 'lack of opportunity', and 'lack of support', often cited by shift workers as to why they do not adhere to physical activity regimens [54, 61].

Besides a lack of clarity on the benefits of physical activity for the shift worker, the reasons for adherence (or lack of adherence) to any advice about physical activity during shift work are poorly understood. [58]. There is some evidence that the majority of shift workers do not follow general guidelines to take more exercise [64]. Whether this is due to the disruptive nature of shift work, feelings that an unhealthy lifestyle is acceptable providing that shift work continues to pay well, or the general reluctance to adopt a healthy lifestyle, is also unclear [83, 91]. There is evidence that adherence to physical activity interventions is poor amongst shift workers. This is illustrated by the study of Atlantis et al.[92]. They recruited and retained 19 participants for physical activity intervention (lasting 6 months) and 23 control participants from a population of 3800 casino workers. Seventy-three percent of these participants were involved in night work. Positive relationships were found between the total amount of aerobic-based exercise completed and the reduction in waist circumference as well as the improvement in maximal oxygen consumption. Besides these encouraging findings, the difficulty of recruiting and retaining shift workers for studies that include a physical activity intervention should be noted. Only 6.4% of the workforce expressed interest in being study participants. Such small recruitment and retention rates represent the substantial challenges that confront researchers into shift work and health.

4. Summary

In this review, some issues surrounding energy balance during shift work have been discussed. Despite a substantial proportion of people being involved in shift work and the current focus on weight reduction in society, there is little specific research covering energy balance issues relevant to shift workers. In the absence of such research, one can only speculate that the well-documented relationships between energy intake, expenditure and factors involved in body mass control apply also to shift workers. Nevertheless, given the known impact of circadian rhythms on human physiology and the added time pressures which shift workers are subject to, speculations about biological responses to eating and physical activity should be made with extreme caution. Not many studies in exercise metabolism or human nutrition have been specifically administered at night, let alone during a bout of repeated night work. In this respect, the ‘triple whammy’ of sleep deprivation, disturbed circadian rhythms and disrupted personal life associated with shift work needs to be researched.

Notions surrounding the promotion of adherence to dietary or exercise interventions might also not apply to shift workers. Not many study reports on such interventions even mention the time(s) that the interventions were administered, both in terms of clock time and in relation to an individual’s shift schedule. Solutions should obviously centre on aspects which promote the individual shift workers to take control of their own destinies in terms of energy balance. Such socio-behavioural factors that influence the adoption of physical activity and a balanced diet have been little researched in shift workers.

Figure 3 is an attempt to summarise all the factors that are relevant to energy balance in shift work. All the behavioural and biological issues which relate to the shift worker have been listed, and there has been an attempt to deal with themes that are common to both energy expenditure and energy intake. Behavioural and biological factors which influence energy expenditure are presented on the left hand side of the diagram; factors which influence energy intake are shown on the right. It is important to note that the biological and behavioural factors influencing energy expenditure and intake are not mutually exclusive. For example, a shift worker might be obliged to train in the evening for a team-based sport

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before a night shift is worked. Subsequent energy intake might be compromised by circadian-mediated nocturnal decreases in hunger and food palatability.

Given the multiple inputs and outputs of this model of shift work and energy balance, it would be important for future researchers not to study isolated factors. Rather, a multidisciplinary (holistic) approach to investigating the specific problems faced by the shift worker should be adopted. We hope this model provides a framework for such future research.

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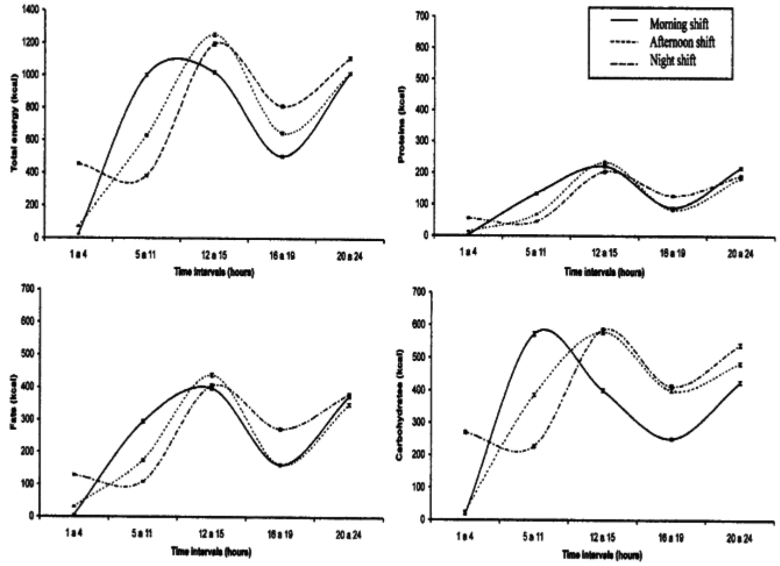

Figure 1.

Circadian rhythms of ingestion of total energy, proteins, fats and carbohydrates during three work shifts (morning, afternoon and night). Total energy intake did not vary between the shifts, but the timing of energy intake and macronutrients differed, e.g. morning shift workers consumed more energy and carbohydrate in the morning hours than other shifts. A cubic spline model was used to smooth the curves (De Assis *et al.* [25]). Permission pending.

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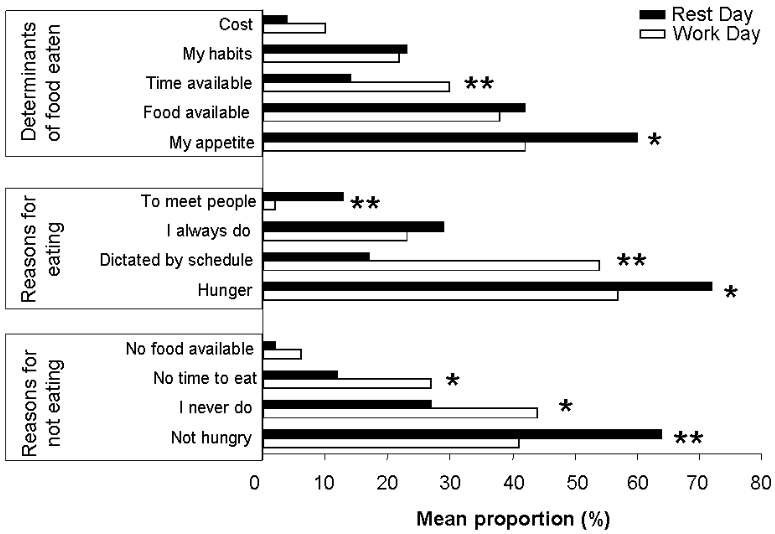

Figure 2.

The effects of a physical activity intervention on fatigue/alertness of female nurses working different shifts (morning, evening, night). The higher the number, the more alert the shift worker was. T - data for an exercise training intervention group. C - a control group which did not undertake the exercise intervention. * - P<0.05. ** - P<0.01. ⌐¬ - significant difference intervention and control groups in terms of mean pre-post changes. Harma *et al.* [89] Permission pending.

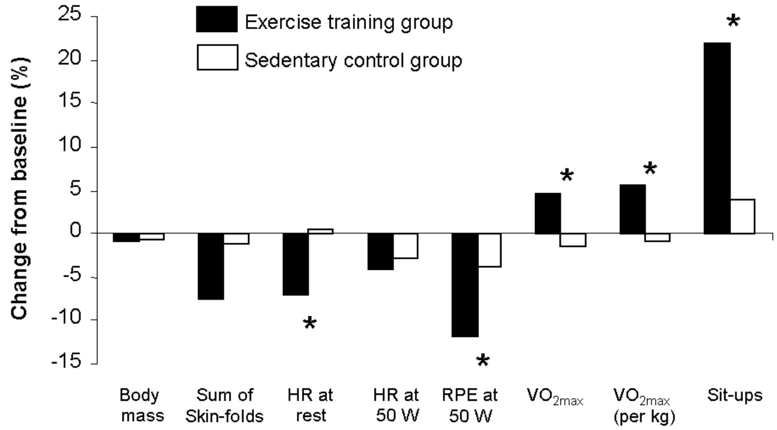

Figure 3.
Schematic presenting the various behavioural and biological factors associated with energy expenditure and energy intake, and therefore energy balance, during shift work. Both energy expenditure and intake can be influenced by behavioural and biological factors, which act in combination to affect energy balance.

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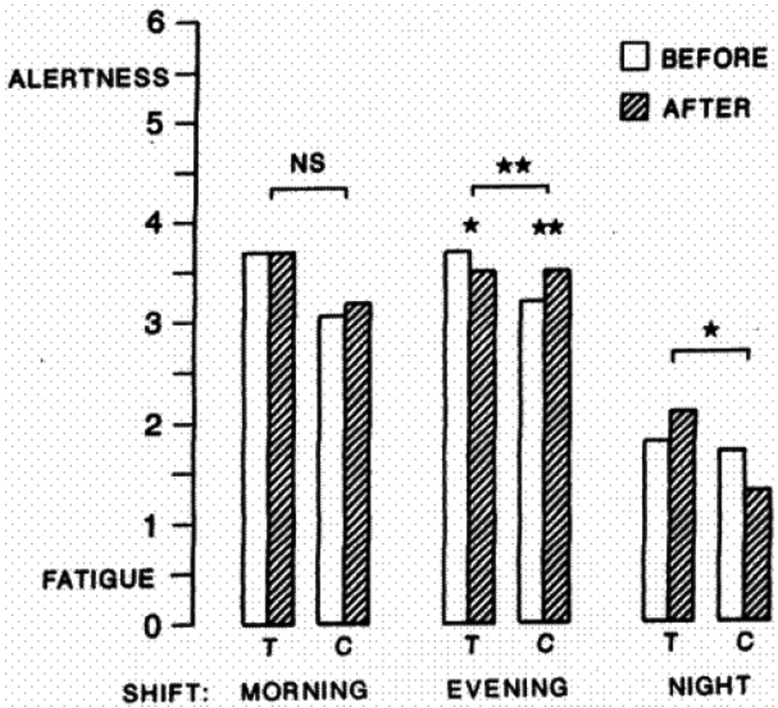

Figure 4.

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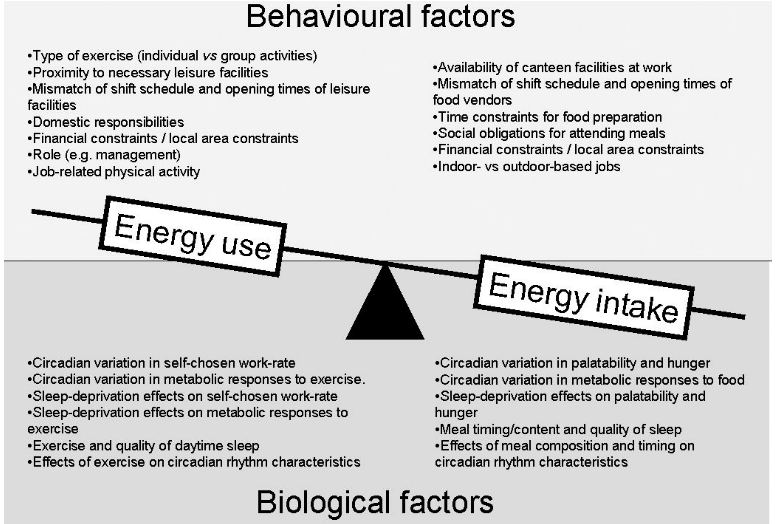

Figure 5.

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Table 1

Mean proportion (%) of night workers (n=43) who stated the reasons for not eating or eating, and determinants of food eaten during work and rest periods. The data are expressed as a proportion of the possible occasions when the option applied. Participants were allowed to indicate more than one response for each of the three main questions. N.S. - difference between frequencies was not statistically significant (P>0.05). Adapted from Waterhouse *et al.* [29]

	Workdays	Rest Days	P-value
Reasons for NOT eating:			
I never do	44%	27%	0.02
I'm not hungry	41%	64%	<0.005
No food available	6%	2%	N.S.
No time to eat	27%	12%	0.01
Reasons FOR eating:			
I always do	23%	29%	N.S.
I was hungry	57%	72%	0.048
To meat partners/friends	2%	13%	<0.005
My schedule dictated that I eat	54%	17%	<0.005
Determinants of food eaten:			
My appetite	42%	60%	0.008
My habits	22%	23%	N.S.
Time available	30%	14%	<0.005
Cost	10%	4%	N.S.
Food available	38%	42%	N.S.

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Table 2

The effects of a physical activity intervention on body mass, body composition and physical work capacity of female shift workers. No significant differences in the changes in body mass and body composition (skinfold measurements) were found between the exercise intervention and control groups. Variables relevant to functional performance (e.g. maximal oxygen consumption - VO_2 max) were improved to a greater degree in the exercise intervention compared to the control group. HR - heart rate. RPE - Ratings of perceived exertion. ME - a test of abdominal muscle endurance. NS - not statistically significant (P>0.05). Adapted from Harma *et al.* [89]

Function	Exercise intervention Group				Control group				*P* for difference between mean changes
	Baseline mean±SD	Absolute mean change from baseline	% mean change from baseline	*P* for mean change	Baseline mean±SD	Absolute mean change from baseline	% mean change from baseline	*P* for mean change	
Body mass (kg)	60.3 ± 7.1	−0.6	−1.00	0.01	63.6 ± 7.9	−0.5	−0.79	NS	NS
Skinfold (mm)	33.2 ± 10.5	−2.5	−7.5	0.01	35.7 ± 11.8	−0.4	−1.1	NS	NS
HR at rest (beats min^{-1})	72.1 ± 12.4	−5.0	−6.9	0.001	64.7 ± 11.2	+0.3	+0.5	NS	0.05
HR at 50w (beats min^{-1})	111.3 ± 13.1	−4.7	−4.2	0.01	105.3 ± 10.9	−2.9	−2.8	NS	NS
RPE 50w (6–20)	10.1 ± 1.8	−1.2	−11.9	0.001	10.5 ± 2.0	−0.4	−3.8	NS	0.05
VO_{2max} (L. min^{-1})	1.99 ± 0.36	+0.09	+4.52	0.01	2.14 ±0.39	−0.03	−1.4	NS	0.01
VO_{2max} (ml. min^{-1} kg^{-1})	33.2 ± 5.3	+1.9	+5.7	0.001	34.1 ±6.7	−0.3	−0.9	NS	0.001
ME (sit ups $30s^{-1}$)	13.3 ± 3.3	+ 2.9	+21.8	0.001	12.9 ±2.1	+0.5	+3.9	NS	0.001