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Stress, Fatigue, Health, and Risk of Road Traffic Accidents Among Professional Drivers: The Contribution of Physical Inactivity

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■ **Abstract** Strategies to achieve ambitious targets for reducing road accidents (34) have largely focused on engineering and technological advancements, the modification of occupational demands, and, to a lesser extent, human factors. These factors include stress and psychological states; sleep, fatigue, and alertness; and health status. Physical activity appears to influence all these human factors but has not previously been systematically considered as a direct or indirect risk factor for driver accidents. This chapter provides an overview, within an evidence-based framework, of the impact each of these human factors has on driver performance and risk of at-work road traffic accidents and then examines how physical (in)activity may moderate and mediate these relationships. Finally, we consider practical implications for work site interventions. The review aims to offer an evidence base for the deployment of resources to promote physical activity, manage stress, facilitate sleep, reduce fatigue, and enhance alertness to improve physical and psychological health among professional drivers.

INTRODUCTION

Professional drivers make a significant contribution to road traffic accident statistics (8, 50) at an extraordinary human and financial cost (49a). A number of studies have shown that workers who drive as part of their occupation have a higher accident risk than does the general driving population, even when a greater exposure to risk is factored out (8, 18, 77). An understanding of the antecedents of accidents, for different kinds of organizations with different kinds of professional drivers, is essential to designing effective interventions to reduce fatalities and serious injuries. Indeed, both the United Kingdom and the United States have set national targets to reduce accident involvement [40% reduction in the United Kingdom by 2010 (16);

41% reduction in large truck fatalities from 1996 to 2008 in the United States (34)]. Efforts to do so have focused largely on in-situ driver-assisted technologies, drug and alcohol testing, regulation of working conditions (e.g., length of shift), and advice on prescribed and over-the-counter medication. A number of other factors, including stress and emotions, fatigue, sleep deprivation, and health status, have been independently linked to increased risk of at-work accidents. Although driver stress and fatigue appear to be major contributors to at-work road traffic accidents (11, 78), it is less clear which factors contribute to driver stress and fatigue.

Physical activity has been reported to effectively influence stress and psychological states, fatigue, sleep, and health status (17, 113), but less scholarly focus has been given to the effects on work-place safety (102). In the driving context, only one study (105) has reported a direct connection. Drivers engaging in more than one weekly session of exercise had 0.78 accidents per driver, whereas less-active drivers had 1.05 accidents over a two-year period. This was not, however, a main element of the Dutch study of long-distance bus drivers, and there were inherent limitations with the methods used (e.g., measure of physical activity). In contrast, other studies have attempted to consider if heavy exercise causes commercial driver accidents (86) as a result of fatigue. Clearly there is a need both to understand the effects of exercise directly and indirectly on accident antecedents (e.g., stress, fatigue, and health status) and also to develop and examine the effectiveness of physical activity interventions on risk of driver accidents.

Definitions

It is first important to define the terms physical fitness, physical activity, and exercise within the context of chronic and acute exercise (12).

1. Physical fitness is a set of attributes that people have or achieve that relates to their ability to perform physical activity.
2. Physical activity is any bodily movement produced by skeletal muscles that results in energy expenditure.
3. Exercise is planned, structured, and repetitive bodily movement purposefully done to improve or maintain one or more components of physical fitness or health.

Both the chronic and acute effects of physical activity (or exercise) have been examined. Chronic exercise involves regular participation over time (e.g., 10 weeks, at least 3 days a week for 20 min at vigorous intensity at a level that would make talking difficult, or at least 5 days a week for an accumulated 30 min at moderate intensity, such as a single session or three brisk 10-min walks at a level that would still permit talking). Acute exercise involves a single period of exercise.

In the present context, chronic exercise may enhance fitness and coping resources and result in improvements in or reduce the risk of ill health. There is reason to suppose that acute exercise may have short-term effects that have an impact on driver behavior and cognitive performance (e.g., increased alertness).

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Purpose

This review provides a framework (see Figure 1) founded on relevant literature published in diverse areas of scientific inquiry, which will help guide future research, synthesis, and interventions. Complex links clearly exist between stress, fatigue, sleep, health status, and driver accident risk, but the purpose of the review is to

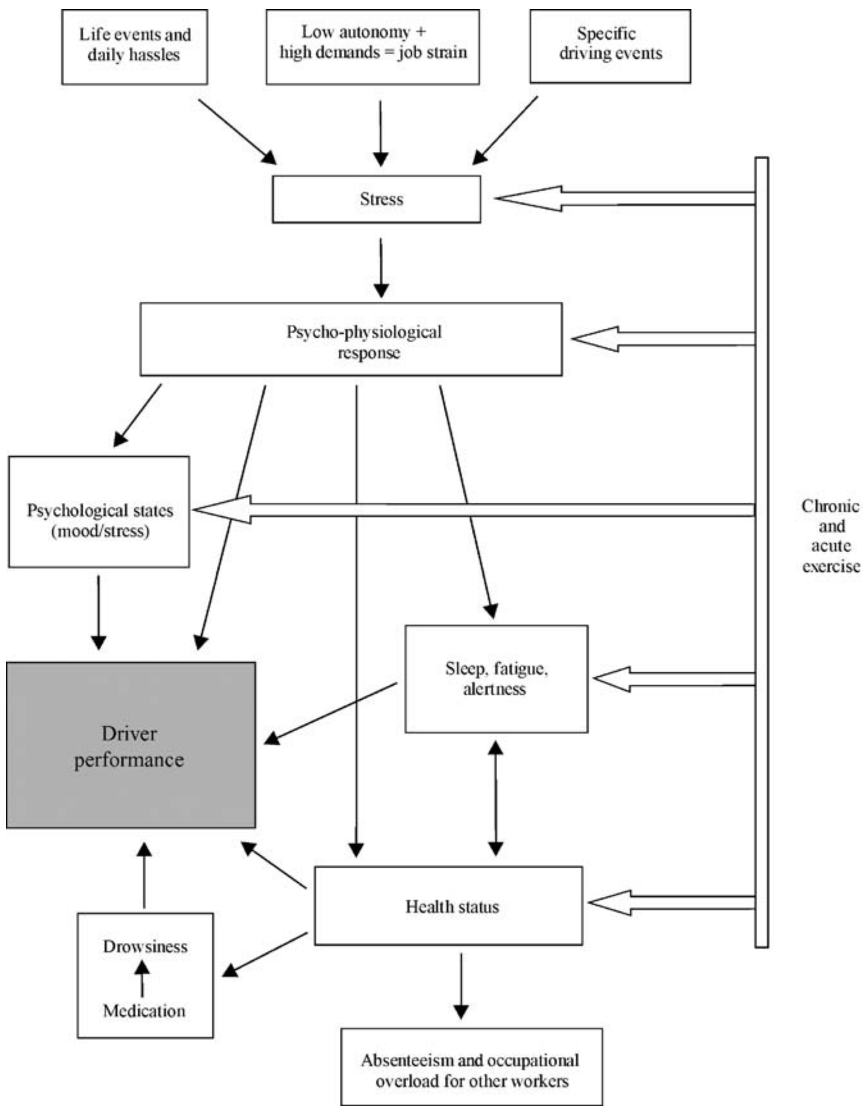

Figure 1 A framework for linking chronic and acute exercise to driver stress, fatigue, health status, and performance.

consider critically the possible impact of physical (in)activity on these relationships as both a moderating (individual difference in response to chronic exercise) and mediating [a temporary period of (in)activity] variable. Finally, we consider the effectiveness of interventions to promote physical activity among professional drivers.

STRESS, PSYCHOLOGICAL STATES, AND DRIVER PERFORMANCE: EFFECTS OF (IN)ACTIVITY

Driving requires sustained attention in complex dynamic tasks and detection of changes in the task environment to search for potential hazards. Perception of hazards may be affected by driver stress, especially for professional drivers who often have to adhere to strict schedules and timetables (21). Driver stress results from a continual interaction of intrinsic and extrinsic factors, e.g., life events and daily hassles (100) of driving moderated by a number of individual differences.

Driver stress vulnerability relates to cognitive processes of appraisal and coping specified by transactional models of stress (76, 79). Demands may exceed perceived capability or resources: Stress factors (and outcomes including fatigue) were associated with performance impairments primarily in underload conditions (78). The main intrinsic sources of professional driver stress vary according to the type of vehicle being driven and the nature of the work. Among company car drivers (18), heavy goods vehicle drivers (114, 117), and long-distance public service vehicle drivers (69, 83, 98), time pressures (particularly on congested roads) are a common factor, combined with long hours spent driving. In an industry with a shortage of skilled drivers, poor health status and a consequential high absenteeism (121), and low profit margins, inevitably some employers may place excessive demands on drivers. For example, in the operation of buses in urban areas workload has high demands with little control over ability to make decisions to help cope with the demands of the job (22, 42). Driving buses can also be socially isolating and involve dealing with difficult passengers. It also requires heightened alertness to deal with inconsiderate road users who may miscalculate the operational capabilities of large vehicles and behave aggressively in response to a slow-moving bus making frequent stops. Occupational stress can also spill over into home life because of split schedules and rotating shifts. For other professional driver groups, there may be different issues: For example, with emergency service drivers, additional stress can arise from high-speed driving in pursuit of offenders or to reach an accident scene (21). Although we may view the framework in Figure 1 as causal, undoubtedly there are reciprocal and interacting relationships. For example, an accident history, inadequate sleep and fatigue, poor health status, and negative psychological states may all independently and in combination have an impact on how occupational events are interpreted (i.e., perceived demands) and on their associated perceived resources for coping.

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So how does driver stress affect the health and safety of the professional driver? Greater traffic congestion and time pressures predicted aggression, irritability, frustration, and negative mood (53). The acute and chronic nature of daily work strain and driving events leads to heightened psycho-physiological responses (106, 114). Drivers often experience symptoms of driver stress such as worry, irritation, and anxiety. The cognitive interference model for adverse effects of stress has been formulated from extensive research on test anxiety. The diversion of resources away from the task resulting from interference becomes increasingly detrimental to performance as task demands increase. Attentional overload can occur when resources become inadequate for the total processing load imposed on the cognitive system. For example, a high-anxiety condition during a simulated drive resulted in slower and less accurate identification of peripheral lights and significant performance decrements in central and peripheral tasks when compared with a low-anxiety condition (60). However, this model neglects a person's active attempts to cope with stress-related demands through compensation and task-focused strategies. Therefore stress-related impairment may be a function of failure to match effort with workload rather than with resource insufficiency. The driver stress inventory (DSI) (80) has been used to show that more severe stress reactions may disrupt driver performance and reduce safety (23).

With repeated exposure to stressful driving contexts over the course of a journey, fatigue symptoms may develop (73). Although driver fatigue has been conceptualized as a consequence of circadian disruption and sleep deprivation (56) leading to reduced alertness and impaired performance (4), driver stress has hiterto not been linked with circadian disruption or sleep deprivation.

Driving for a sustained period can increase fatigue and alter cardiovascular and neuroendocrine function (104). Ambulatory studies of professional drivers have demonstrated cortical deactivation in response to continuous driving over monotonous and repetitive environments (7). Therefore, arousal is important for maintaining the vigilance and phasic alertness to stimuli required for safe driving. Quantity and quality of sleep can inevitably be affected by overstimulation of the neuro-endocrine system, as a compensatory coping mechanism for dealing with driver-related fatigue, and compounded by overuse of legal stimulants (e.g., caffeine products). Psycho-physiological recovery from driving shifts has recently been monitored (106) to investigate in situ responses to fatigue debt, but we know little about how drivers use different coping strategies and whether exercise can be used to influence chronobiological responses among drivers. However, a measure of need for recovery as an indicator of the level of work-related fatigue among coach drivers has been used to demonstrate that this variable can predict psychosomatic complaints, sleep disorders, and occupational burnout (104).

Stress and Health Status

Stress-related disorders have been widely recognized: the Department of Health in the United Kingdom estimated that 80 million working days are lost annually owing to anxiety and depression at a cost of £5.3 billion (~$9.31 billion) (15). In addition, health care expenditure for the treatment of anxiety and depression has been estimated at more than £1 billion (~$1.76 billion). Stress has been linked with cancer, coronary heart disease/stroke, accidents, and poor mental health (16, 108). The mechanisms have been considered both indirect, through effects of stress on health behaviors such as diet (120) and smoking (61), and direct, through biological changes including neuroendocrine changes and adaptations (1), development of the metabolic syndrome and insulin resistance, disturbances of blood coagulation, and disruption of immune responses (2, 10). Recent research has also focused on psycho-physiological measures of recovery from work as an indicator of effective coping (104), which mediates the link between a demanding work environment and health status. Stress-induced fatigue may also increase the use of caffeine, which in turn may disrupt coping and adversely affect sleep and health status.

The role of personality in moderating the effects of stress on driver accidents has received some attention (23), but little consideration has been given to the role of an individual's level of physical fitness and physical activity as an individual difference factor.

Chronic and Acute Exercise, Stress, and Psychological States

Chronic and acute exercise may help to reduce stress and its psychological and physical responses in a number of ways (84). First, from a cognitive perspective, being more physically active may increase resilience, hardiness, physical self-perceptions and self-concept (see 111), and perceived energy, and reduce fatigue; these attributes influence how we initially cognitively appraise events that are intrinsic and extrinsic to the occupation. Physical fitness, as a coping resource, may also enable a more positive secondary appraisal of stressors (65). Engagement in acute exercise can also provide a distraction away from rumination about stressors, particularly if it involves social interaction with others. Second, from a psycho-physiological perspective, improved aerobic capacity or ability to deal with a physical stressor may attenuate our physical response to a psychological stressor (stress reactivity). Attenuated physiological responses (e.g., heart rate, blood pressure, etc.) to, and more rapid recovery from, stressors may leave people feeling less fatigued and more able to cope with events that are intrinsic and extrinsic to the occupation (48).

The past 30 years has resulted in a large volume of literature on physical activity and stress and anxiety, including 29 reviews (74) and 57 (40) reviews, respectively. Recently, an overview (109) was published of systematic qualitative (without meta-analyses) reviews (articles and book chapters) and six quantitative (with meta-analyses) reviews. In summary, the findings point to the following conclusions:

1. Chronic exercise can result in lower subjective (e.g., anxiety) and objective (e.g., blood pressure) indicators of stress responses. When stressors are presented, the evidence for absolute reductions in cardiovascular response

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to stress is more consistent than it is for reduced reactivity (or change) to stressors.

2. Single sessions of moderate intensity exercise, particularly aerobic and rhythmic in nature, can result in lower subjective (e.g., anxiety) and objective (e.g., blood pressure) indicators of stress responses. This evidence has focused almost exclusively on changing anxiety and arousal under normal rather than enhanced stressful conditions, when the effects may be even greater.
3. A single session of moderate intensity exercise may reduce physiological reactivity to a variety of mostly laboratory stressors (48) and enhance recovery after the stressor. Further research is needed for driving-related stressors.

Both chronic and acute exercise can improve subjective tension, depression, and anger/hostility (3). Very vigorous exercise may reduce coping assets (e.g., lower feelings of control, self-confidence, elation, etc.) and increase coping deficits (e.g., easily irritated, feeling run down and drained, feeling less calm, etc.) (87). In contrast, moderate intensity exercise (e.g., at a level that enables continued talking) may enhance coping assets, reduce coping deficits, and provide a sense of physical well-being.

SLEEP, FATIGUE, ALERTNESS, AND DRIVER PERFORMANCE: EFFECTS OF (IN)ACTIVITY

Driver fatigue has been identified as a major cause of serious accidents (14, 56, 81) owing to reduced driving performance efficiency. Over a quarter of long distance lorry drivers reported falling asleep at the wheel at some time during the previous 12 months of driving (81). However, fatigue-related accidents are complex, and numerous factors have been proposed for the causes of fatigue and low alertness implicated in increased driver risk. These causes include (*a*) stress and task demands, (*b*) hours on task, (*c*) sleep deprivation and disorders, (*d*) time of day and circadian variation, and (*e*) effort investment and motivation.

Earlier we considered the role of stress as a cause of fatigue, but clearly other causes exist and there is a need for further conceptual clarity. Driver stress and fatigue are dependent on both driving-related and nondriving-related factors, often in different ways. Many investigators prefer to discuss the multifactorial concomitants of both driver stress and fatigue. For fatigue, there is a circadian variation in adrenaline excretion, noradrenaline, performance, and fatigue ratings (36). Peak of circadian variation for each of these variables was at a different time of day (37), and adrenaline excretion was not significantly correlated with performance (36). In terms of stress physiology and fatigue, this suggests that driver stress and fatigue are conceptually distinct but related processes that both interact with chronobiological changes.

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Professional driver fatigue may result from the occupational requirement of driving for long hours, with progressive withdrawal of attention from the road and traffic demands particularly in familiar environments (9) involving cognitive underload rather than excessive information-processing demands. Some researchers believe that prolonged driving in monotonous conditions should be characterized as a demanding task that is associated with effort costs, even though working memory load and controlled information processing demands are low (115). However, the contribution of time on task in the development of fatigue may be small in comparison to time of day, poor sleep, and individual differences (e.g., the point at which aversion to invest effort and stop driving because of subjective fatigue symptoms begins to develop) (90). Also, prolonged driving will not necessarily cause serious problems if drivers can choose the speed and safety margins they prefer and if they can stop driving if they so desire (9, 115). Yet with strict occupational scheduling demands disrupting the adoption of safety margins in prolonged driving, detriments to central task components such as steering have been observed, although performance in high-priority subtasks such as hazard avoidance remained intact. Fatigued drivers can also maintain adequate performance and protect task priorities (54) through compensatory strategies such as driving slower (if organizational demands permit). The combination of being in a hurry (driver stress) and prolonged driving may be particularly dangerous.

Chronic and Acute Exercise, Sleep, Fatigue, Alertness, and Accident Risk

The potential role of exercise in reducing work-related fatigue (and accident risk) is complex, and any brief discussion is in danger of oversimplifying the interrelationships. In the previous section on stress, a link between stress and psychophysiological response and sleep was suggested. Long-distance coach drivers who did more than one session of exercise per week (to increase physical condition) reported lower scores on their need-for-recovery scale (107), but the study did not consider if chronic or acute exercise facilitated psycho-physiological indicators of recovery or ability to sleep. In contrast, others (93) have attempted to determine if physical exertion (e.g., cargo loading) causes fatigue and reduced driver alertness.

Two research questions of significance to driver safety research are

1. does chronic and acute exercise result in improved quality and quantity of sleep? and
2. does chronic and acute exercise result in enhanced psychological states such as vigor, alertness and activation, reduced fatigue, drowsiness, and deactivation?

The five recent reviews highlighted in Table 1 largely draw the same conclusions that chronic and acute exercise can influence quality and quantity of sleep. Also, subjectively, people report that exercise is an important behavior for sleep hygiene.

TABLE 1 Review papers on effects of chronic and acute exercise on sleep*

Reference	Type of paradigm	Type of review	Main results
(71)	Acute and chronic	Meta-analysis: Acute—32 studies (828 ESs); Chronic—12 studies (274 ESs)	Acute ex → positive effects on 7 key sleep measures (ES = 0.14–0.75). Chronic exercise → positive effects on 5 key sleep measures (ES = 0.40–0.94). Effects greater for females, less fit, older, and when exercise is longer, aerobic, not late in evening.
(24)	Acute	Narrative	Positive effect of exercise in A.M. and of moderate intensity in P.M. Sleep-disruptive effect of exercise if high intensity, long duration, or unaccustomed.
(92)	Cross-sectional; acute; chronic; bed rest	Mainly narrative and also meta-analysis (with few details)	Consistency across epidemiological, acute, and chronic studies for low-moderate effect of exercise but methodological limitations (e.g., limited mainly to good sleepers).
(123)	Acute	Meta-analysis: 38 studies (211 effects)	Moderate ES on 4 sleep measures (0.18–0.52). Effects greater for longer exercise and not late in the day. ES limited by exclusive focus on good sleepers.
(122)	Cross-sectional, acute and chronic	Systematic, narrative	People believe that exercise is an important sleep-promoting behavior. Individuals who exercise regularly have a lower risk of disturbed sleep. Chronic exercise may elicit improvements in sleep in individuals with disturbed sleep. Acute exercise (particularly of longer duration) elicits modest improvement in sleep among good sleepers. Fitness, exercise intensity, or time of day have minimal moderating influence.

*ES = effect size.

The most recent review (122) highlights the complexity of exercise and sleep research and the quest to identify moderating factors and mechanisms.

Studies involving often unreliable, self-reported measures of physical activity and sleep are limited. However, in a recent relatively rigorous trial (67), investigators reported that 16 weeks of community-based exercise consisting of 67 males and females between 50 and 76 years of age resulted in significant net improvements per night in sleep duration (42 min) and sleep-onset latency (11.5 min). Separating out the chronic and acute effects is challenging; these effects may have resulted from an increase in dose of daily exercise due to training. Also, the small sample sizes that typify the more rigorous studies do not allow full analysis for moderating effects of variables such as dose of exercise (e.g., frequency, intensity, duration), timing of exercise, and initial sleep status. One of the key issues to address is not the acute effects of a single session of exercise in a day, which is what most of the literature has considered, but what the effect of total daily energy expenditure on sleep is (122). This is more difficult to assess, but the use of accelerometers should advance the field. Those in sedentary occupations, such as driving, may be particularly prone to sleep disorders unless they compensate with regular exercise when not driving. Also, further understanding of the mechanisms by which exercise influences sleep is needed to prescribe exercise for sleep enhancement (122).

If inadequate sleep and stress (intrinsic and extrinsic to work-related driving) can result in fatigue, drowsiness, and deactivation, can chronic and acute exercise influence these psychological states? In a review of 20 studies (82) designed to investigate the effects of chronic aerobic exercise, significant increases in vigor [Effect Size (ES) $= 0.40$] and reductions in fatigue (ES $= -0.27$) were reported. An extensive narrative review confirmed that less-active people report greater fatigue, and chronic exercise results in greater levels of perceived vigor and alertness and less fatigue (3).

There is a general perception that acute exercise will induce fatigue and physical exhaustion, which may be detrimental to driver performance, rather than increase activation and alertness (see 93). As a result, individuals may seek to regulate psychological states (e.g., fatigue) by avoiding exercise in favor of stimulants such as sugar snacks and caffeine. An accumulation of inactivity would result in further deconditioning and reduced energy. It is therefore critical to consider, within a conceptually clear framework, the actual relationship between acute exercise and these psychological states (27, 28).

Laboratory-based studies suggest that moderate- to high-intensity (vigorous) acute exercise can lead to increased levels of fatigue and exhaustion in the later parts of an exercise session, and it takes some time (depending on the length of exercise and an individual's fitness level) before these feelings return to normal. In contrast, feelings of revitalization occur during and after low-moderate intensity exercise and last some time (depending on the length of exercise) (26).

Fairly rigorous field-based studies (e.g., involving pagers and other sampling methods) have shown that low-moderate intensity exercise (e.g., walking) results

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in significantly higher levels of revitalization, with the effects lasting throughout the day, hours after the exercise bout occurred (38, 39). Indeed, 10-min walks were associated with increases in self-rated energy lasting for 2 h, whereas a sugar snack condition was associated with significantly higher energy and reduced tiredness for 1 h, followed 1 h later by increased tiredness and reduced energy (112). In another study that involved walking (in both laboratory and natural settings) (25), the circumplex model (99) was used to investigate the effects of exercise on valence and arousal. Across 4 experimental studies, the results consistently showed that short (10–15-min) bouts of walking was associated with increased activation (and a state of calmness and relaxation).

A study to compare exercise and behavior typically used by drivers for mood regulation (i.e., sugar snacking) has been conducted (112). However, further research is needed to understand the effects of brief periods of moderate intensity exercise in comparison with other popular stimulants used by drivers. For example, another study showed that coach drivers consumed an average of 12 cups of caffeine per day on long-distance trips and, perhaps not surprisingly, also showed signs of sleep disturbance, unwanted daytime sleepiness, and elevated stress hormones to compensate for fatigue debt (106). Exercise may compare favorably with a progressive increasing use of such stimulants to reduce fatigue.

Other research has used performance measures, such as reaction time, visual tracking, and other cognitive tasks, as indicators of fatigue and alertness. In a unique study involving haulage drivers (reference 34 cited in 93), investigators reported that after 90 min of manual lifting and moving boxes, instead of causing a detrimental effect on performance as hypothesized, there was an initial invigorating positive effect on vigilance and response time to likely simulated crash situations. The effect faded with time. Following an afternoon manual loading/unloading session, performance deteriorated discernibly but returned to baseline near the end of the day. This suggests that exercise may have different effects at different times of the day within a circadian cycle. The daily manual tasks (morning and afternoon) took place within a daily schedule of 14 h on/10 h off (with 12 h of driving), with a weekend rest/recovery period of 58 h between successive weeks following the study protocol. The researchers reported that following the manual routine, the drivers tended to sleep longer on the first night of the weekend. The study should be replicated with more careful monitoring of exercise intensity by using heart rate monitors and fitness measures to determine relative physical workload.

Finally, aging research on the protective role of exercise on cognitive decline and impairment is rapidly gaining momentum (6, 31, 44, 75, 97). The transfer of evidence to the context of driving would be speculative at present, but several plausible mechanisms may explain how inactivity results in cognitive impairment: Exercise may improve cerebral blood flow and neuronal growth and positively affect other risk factors for cognitive decline such as stress hormones, lipids, insulin levels, and immune function.

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HEALTH STATUS AND DRIVER PERFORMANCE: EFFECTS OF (IN)ACTIVITY

Health status has an impact on the safety of drivers (46). More than 300 fatal two-vehicle trailer-truck accidents were investigated in one study (47). The probability of being principally responsible for an accident increased by a factor of 3.5 if the driver had a chronic illness. One study (62) reported that drivers with cardiovascular disease were twice as likely to have an accident and be at fault than were healthy drivers. In other studies, diabetic heavy goods vehicle (HGV) drivers were more likely to have an accident than were nondiabetic HGV drivers (19, 72). Chronic medical conditions have also been associated with increased accident involvement among older drivers (52). There is no research on the effects of depression on driver risk, although recent evidence suggests that depression influences cognitive functioning (i.e., attentional processes) (32).

Further work is needed to understand how physical and mental health statuses influence risk of driver accidents. In a cohort study of 10,525 New Zealand men and women, obese drivers were twice as likely to have an accident (120a), although in considering the public health impact of obesity, these effects have typically not been considered (e.g., 13, 116). Much has been written about sleep apnea syndrome and driver safety, and a reduction in obesity, through lifestyle management (including physical activity), could reduce the problem (91). Another possibility may be through pharmacological mechanisms that impair driver alertness and information processing. There is also the potential for unwanted sleepiness in drivers using certain over-the-counter medicines such as antihistamines, opioid analgesics, and muscarinic antagonists (55), but little is known about the effects of physical activity on pharmokinetics (66).

Finally, in the United Kingdom, a figure of more than 18 million days of sickness absence is attributable to obesity and its consequences. The National Audit Office (89) has estimated that obesity-related costs are £135 million (∼\$237 million) for hypertension, £127 million (∼\$223 million) for coronary heart disease, and £124 million (∼\$218 million) for Type 2 diabetes. Diabetic employees are likely to use 32 days per year of sickness absence, whereas nondiabetic employees used 17 days (103). We are not aware of any attempt to estimate the implications of absenteeism (or indeed premature retirement due to ill health) on occupational stress (resulting from greater work demands placed on those remaining at work); this probably has significant consequences for driver safety in the transport industry where there is often a shortage of skilled workers.

Chronic and Acute Exercise, Health Status, and Accident Risk

More than 50 years ago, it was first reported that less-active London bus drivers had a higher risk of coronary heart disease (CHD) than did more-active bus conductors (85, 94). It is now clear that regular physical activity is beneficial for many dimensions of health, well-being, and quality of life, with a particular concern for physical inactivity and obesity (17, 113). Inactive and less-fit people, compared with physically active and more-fit people, are almost twice as likely to die from cardiovascular disease (5). From a public health perspective, the greatest protective effects are likely to be seen from an increase in physical activity among the least active and least fit. Physical activity at an intensity of 4–6 METS (1 unit of metabolic energy expenditure is equivalent to sleeping) (equivalent to brisk walking) is adequate for reducing the risk of CHD (88) and stroke (119). This can be achieved from an accumulation of short sessions (i.e., 3×10 min per day) on most days of the week.

Physical inactivity is a major risk factor for the development of Type 2 diabetes (64). Regular walking and cycling is sufficient to reduce the risk for Type 2 diabetes (59, 119) with each increment of 500 kcal in weekly energy expenditure (e.g., 90 min of brisk walking) associated with a 6% decrease in the age-adjusted risk (up to 3500 kcal/week^{-1}). The number of hours of inactivity, such as television watching (independent of exercise), is strongly associated with risk of diabetes (58). This finding places those in sedentary occupations such as driving at considerably greater risk. Indeed, physical activity may be a more important contributor to Type 2 diabetes prevention than dietary change alone, but both are important.

Chronic low back pain (CLBP) is a major reason for absenteeism. Inactivity, particularly with poor posture (96), is a major risk factor for the development of CLBP, and chronic exercise (involving flexibility, strengthening, endurance, and core stability activities) appears to have a protective effect (118).

In summary, physical inactivity has become so endemic in industrialized countries, and particularly among certain occupational groups such as professional drivers (49, 70), that the overall population attributable risk for CHD in particular (and possible other conditions) is greater than any other lifestyle risk factor. The contribution of physical inactivity on driver health status as an important risk factor for accidents has not previously been considered in the literature (13).

IMPLICATIONS FOR INTERVENTIONS

Increasing physical activity may be particularly challenging among professional drivers owing to variable shift work, demanding occupational schedules and stress-induced fatigue, lethargy from being sedentary, and a social culture that often reinforces physical inactivity (35). Physical activity interventions, aimed at changing predisposing factors (e.g., attitudes, beliefs, and values), reinforcing factors (e.g., attitudes of line managers, union representatives, and occupational health workers), and enabling factors (e.g., opportunities to cycle, leave bikes and shower at work, use an exercise facility while traveling, have flexible shifts to facilitate more physical activity, and provide financial incentives for more active lifestyles) (41, 110), can be effective (63). Yet there has been a conspicuous absence of interest in the role of exercise in work place health and accident risk among professional drivers (20, 43, 101).

In a Swedish study, counseling by physicians led to significant increases in physical activity after 6 months among 69 professional drivers (29, 30). The drivers ranked exercise first among several lifestyle changes as a way in which they could influence their own well-being (51). Both a health profile assessment (including individualized counseling) and a health examination were associated with increases in aerobic fitness and physical activity and a reduction in total cholesterol and perceived stress up to the 18-month follow-up. Availability of variable working hours was the most common obstacle to changing a health habit. Finally, a review of 13 studies was conducted that involved stress prevention interventions for bus drivers (68). Physical activity was identified as a major component (within a multifaceted intervention) in only two studies, both involving bus drivers. Fitness training and an informational course, respectively, appeared to reduce absenteeism, but it is impossible to apportion effects to any specific component of the intervention. Driver wellness programs are emerging for both small and large companies (33), and the systematic evidence reviewed here can help underpin their scope and implementation. Certainly, drivers have identified physical inactivity, weight, fatigue, poor diet, and stress as priority concerns.

CONCLUSIONS

In conclusion, there are several ways in which increased physical activity may improve driving performance and potentially reduce accident risk. These include effects on the following: stress and psychological and physiological responses; enhanced sleep and alertness, reduced fatigue, and improved cognitive functioning; and enhanced psychological and physical health status. There is sufficient global evidence that professional drivers are less active than is the general population. To test the beneficial effects of physical exercise, research is needed at four levels:

1. Epidemiological studies are needed to identify relationships between physical activity levels and driver stress, fatigue, sleep, health status, and accidents among specific subgroups of professional drivers (e.g., local bus drivers, long-distance coach drivers, HGV drivers, company car drivers, etc.). An economic evaluation of the potential financial implications of physical (in)activity among specific professional drivers would follow.
2. Intervention studies are needed to examine the effects of chronic exercise on driver performance in natural and controlled settings (e.g., using driving simulators), particularly for drivers who report high stress, poor sleep, and poor health status.
3. Studies are needed that examine the acute effects of exercise (in different doses, intensity, and duration, but particularly behaviours such as walking, which are convenient and likely to be adopted) on simulated driving performance, particularly among drivers who report high stress, poor sleep, and poor health status.

4. There is a need for research that examines the effectiveness of driver work site interventions (to promote physical activity) to determine how best to promote physical activity to groups of professional drivers through multi-level interventions (at the organizational structure, work site environments, and individual levels).

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