CONSTRUCTION WORKER SLEEP DEPRIVATION AND ITS EFFECTS ON PERSONAL SAFETY

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Sleep deprivation contributes to fatigue which can have a profound effect on an individual's wellbeing, work performance and safety. To investigate this phenomenon, an initial study was conducted on a sample of construction workers on a large construction project in Vancouver, Canada. This paper reports on the results from the workers wearing an actigraph 24-hours per day for a full week to precisely measure their sleep and rest. The results enabled sleep efficiency and mental effectiveness levels to be determined by correlating them to Blood Alcohol Concentration levels. The study concluded that there was some degree of fatigue-impairment with a resulting decrement in performance of the workers studied which increased the risk of accidents and lost productivity. A further fatigue awareness survey amongst construction professionals revealed that fatigue impairment is viewed as a problem, and that fatigue-impaired workers, who were impaired to the same extent as workers on illicit drugs or alcohol, somehow performed better and were less of a concern in the workplace. The paper concludes that there is currently a miss-match between the perceived threat from sleep deprivation and its potential resulting consequences and that further research is needed into how fatigue-factors should be measured and managed on construction projects.

Keywords: sleep deprivation, fatigue, operatives, accident, productivity.

INTRODUCTION

Sleep deprivation is pervasive in modern society. It contributes to fatigue which can have a profound effect on an individual's wellbeing, work performance and safety. Not all but some commercial sectors recognize this relationship and have conducted studies to apply some of the general knowledge of fatigue and sleep to their operational settings. In several instances the resulting guidelines and improved operational practices has helped reduce losses and improved worker wellness and safety.

Fatigue has been defined (Strauss 2003) as "a non-pathological state resulting in a decreased ability to maintain function or workload due to mental or physical stress". Associated with fatigue are two key physiological factors, loss of sleep and disruption of the circadian cycle which is the physiological process controlling many bodily functions such as sleeping, digestion, hormone secretion, body temperature and alertness. Regardless of how one enters into a fatigued state, adequate sleep is the only naturally occurring cure.

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Powell, R and Copping, A (2010) Construction worker sleep deprivation and its effects on personal safety. *In:* Egbu, C. (Ed) *Procs 26th Annual ARCOM Conference,* 6-8 September 2010, Leeds, UK, Association of Researchers in Construction Management, 203-211.

Inadequate sleep has been associated with numerous major work-related accidents but a common problem is that individuals do not either understand their state of fatigue or its consequences or both. Over the past 40 years, researchers have developed a much better understanding of sleep, circadian rhythms and performance effects associated with these. For several decades, researchers (Levine, Roehrs *et al.* 1988; Wehr, Moul *et al.* 1993; Dinges, Graeber *et al.* 1996; Rosekind, Co *et al.* 2000; Van Dongen, Rogers *et al.* 2003; Russo 2005; Roth 2006) have found an average sleep requirement for adults of 8 hours per 24-hour period for fully restorative results but most get less than 7 resulting in a sleep deficit (Dinges, Pack *et al.* 1997). Any amount of sleep less than that required by an individual for full restoration results in sleep deprivation. Severe or chronic sleep deprivation can be very serious and dangerous not only to the individual but others who may be impacted by actions of the sleep deprived.

The construction sector can be a difficult and dangerous place to work. The National Institute for Occupational Safety and Health (National Institute for Occupational Safety and Health 2007) reports "Construction is a high hazard occupation. In the US during the period from 1980 through 1995, at least 17,000 construction workers died from injuries suffered on the job. Construction lost more workers to traumatic injury death than any other major industrial sector during this time period. Construction has the third highest rate of death by injury: 15.2 deaths per 100,000 workers. Only mining and agriculture experience higher rates."

Risks on construction sites may be heightened due to inclement weather and mobile equipment, different work sites necessitating travel coupled with changing and demanding schedules requiring additional work hours. All possibly increase stress and fatigue. Factors such as these challenge human physiology and can result in performance-impairing fatigue leading to higher worker risk. Continuous improvement of worker performance, productivity and safety is possible but starts by acknowledging and managing these factors. Rosekind (Rosekind, Gander *et al.* 1996)(p 157) noted, ignoring them "…can lead to decrements in performance and capability as well as the potential for incidents and accidents that can result in tremendous societal and individual costs".

It is possible that fatigue via sleep deprivation is a key component of the risk profile facing construction workers of British Columbia but it has not been investigated in British Columbia or any other regions whilst other industrial sectors have recognized that fatigue is a key component of workplace safety and employee wellness and therefore a factor which must be managed. The aviation industry (Graeber, Lauber *et al.* 1986; Gander, Nguyen *et al.* 1993; Rosekind, Smith *et al.* 1995; Dinges, Graeber *et al.* 1996) and the transportation industry (Transport Canada 1996; National Transportation Safety Board 1999), were early promoters of research to better understand fatigue's impact on performance, accidents and its management. The construction industry has many elements found in other sectors which have studied fatigue including operation of heavy equipment, shift work (Akerstedt 1988; Dijk and Czeisler 1995; Monk, Folkard *et al.* 1996) and long hours (Spengler, Browning *et al.* 2004; Dong 2005) making it a logical concern after consideration of the findings from other sectors. Understanding fatigue levels in the construction industry as well as any companion risk associated with accidents introduced by workers from this factor was the driver of this study.

RESEARCH METHOD

Initial sleep study

The construction workers in this study were from one of British Columbia's (BC) mega projects called the Canada Line project (SNC-Lavalin Inc. 2007), a 18 km automated rapid transit system in the metropolitan Vancouver area. The workers wore an actigraph (a small device worn around the wrist to record the motion of the wearer) for 7 days to capture their actual wake and sleep activity. The results were analysed with the fatigue software model SAFTE© (Hursh, Raslear *et al.* 2006). The study was conducted in August and September of 2007. 113 sessions were conducted where 95 different participants wore an actigraph.

Sleep survey

To verify the measured sleep data, the workers also kept sleep logbooks. For further validation the measurements were compared to results from a separate survey where workers of the same project estimated their sleep. 125 responses were received from a distribution of about 500 surveys.

Fatigue awareness survey

As a follow up to the initial sleep study a fatigue awareness survey was conducted amongst a representative sample of construction professionals in British Columbia and the UK. A 35% response rate was received.

FINDINGS

Measured sleep performance for the participant construction workers ranged from an average of 4.5 hours per day to 8.9 hours per day. Mean sleep values for a week were determined for participants and averaged 6.7 hours per night as shown in Table 1 which also shows the comparison data from the sleep logbooks they kept and from the estimated sleep of workers from the separate survey. The log average was 7.2 hours suggesting participants were getting a half hour more sleep per night than measured. Only 16% of the participants measured met the recommended guidelines of 8 hours of sleep per night as shown in Table 2.

Sleep activity levels, wake periods, sleep efficiency and mental effectiveness levels were determined by correlating to Blood Alcohol Concentration (BAC) levels, to estimate increased risk for the workers due to inadequate sleep.

Table 1: Average sleep values from survey, logbook and actigraph measurements in hours per 24-hour period.

Survey sleep		**Log sleep**		**Survey sleep full**	**Logbook sleep full**	**Actigraph measured sleep full**
Week	Weekend	Week	Weekend	**week**	**week**	**week**
6.2	7.5	7.0	7.7	6.6	7.2	6.7

The percentage mental effectiveness levels were determined for each participant based on original research conducted by Dawson and Reid 1997, which correlated reduced mental effectiveness levels and increased reaction times from fatigue to a BAC level as illustrated in Table 3. Reduced mental effectiveness greater than 10% is taken by the SAFTE© model as outside a normal range. Average increased accident risk was 8.9% for all participants; 7.4% for all office workers and 10.1% for all field workers solely due to inadequate sleep.

Table 2: Distribution of hours slept per 24-hour period.

Hours Sleep Each Day	Percent (Survey)	Percent (logbook)	Percent (Measured)
8+ Hours	8.2%	21.4%	15.7%
7-8 Hours	34.5%	38.8%	27.0%
6-7 Hours	29.1%	30.6%	37.1%
5-6 Hours	18.2%	7.1%	15.7%
< 5 Hours	10.0%	2.0%	4.5%

Table 3: Actigraph-measured values and SAFTE© results

Results from Actigraph measurement	Measured average sleep	10-20% Mental decrement		20-30% mental decrement		30-40% mental decrement		40-100% mental decrement	
		Hours	%	Hours	%	Hours	%	Hours	%
All Workers	6.7	1648	21.1%	432	5.5%	133	1.7%	38	0.5%
Office	6.8	503	14%	166	4.6%	30	0.8%	33	0.9%
Field	6.7	1145	26.7%	266	6.2%	103	2.4%	5	0.1%
BAC Equivalent		0.03%		0.05%		0.09%		> 0.11%	

To put this in perspective, 432 work hours were measured at a BAC equivalency of 0.05%, a level considered unsafe for operating motor vehicles in most parts of Europe. In North America 0.08% BAC is considered legally impaired. Another 133 hours were measured at an equivalent BAC of 0.09% and 38 hours were measured at an equivalent BAC of over 0.11%. For the entire group the estimated average increased accident risk levels ranged from 0.7% to 23.3% solely due to inadequate sleep. While the source of impairment was not alcohol, the effects of inadequate sleep are similar resulting in a more risky work environment for workers and their co-workers.

Age, sleep obtained and accident rates

Averaged accident claims from 2000 to 2006 (WorkSafe BC 2006) show almost 60% came from workers under the age of 40. Workers under the age of 40 recorded less average sleep than workers over 40 (6.6 + 1.9 hours versus 6.9 + 1 hours) with implications that less sleep may be a factor but the statistical significance is weak ($p = 0.22$; CL =95%). More data samples were needed in some of the age categories to allow significant comparisons. Figure 1 illustrates the distribution of the average sleep per 24-hour period by age group as well as the distribution of the samples ages. The added trend line clearly shows the younger the worker the less sleep obtained.

Impairment awareness survey results

There was general consistency in the responses across the two surveys with shifts in views on particular questions. Most importantly, the surveys confirmed that organizations have different views of impairment based on cause of impairment and do not view the issue as one of 'Fitness-for-Duty'. There was surprising agreement regarding fatigue as a source of impairment in the workplace such as viewing it as the most serious factor, the most prevalent factor, the biggest problem and the number 1 factor associated with productivity loss as shown in Table 4.

Most of the surveyed organizations do not have impairment policies or tests for impairment which speaks to the ambiguity associated with its relevance in the workplace.

Almost one third of the respondents were aware of an occupational injury in the last 12 months where impairment was a contributing factor. This reiterates the prevalence

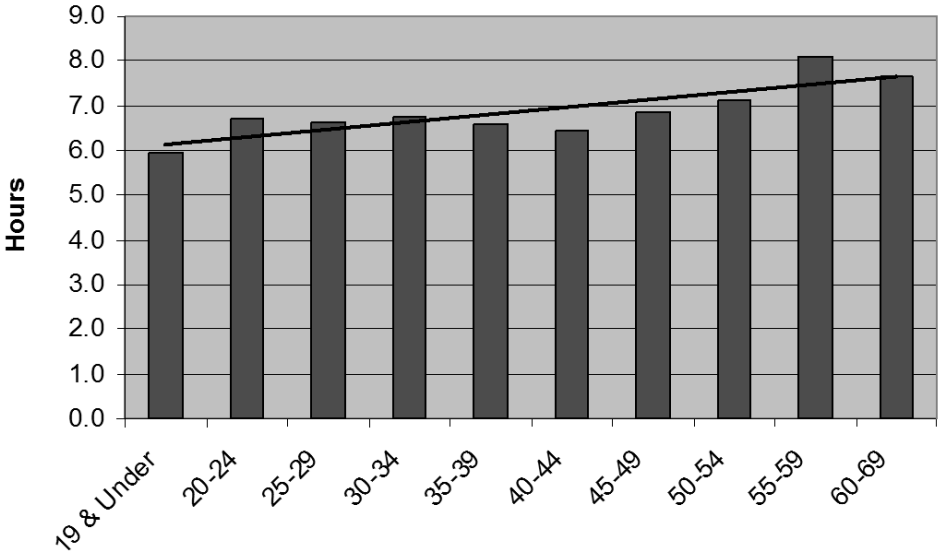

Figure 1: Measured sleep values by age category

of the impairment in the workplace and its tie to workplace productivity loss via accidents.

Detection techniques were similarly undeveloped. 'Observation' was the technique receiving the highest response for 'Alcohol use', 'Fatigued' and 'Illicit drug use' from all respondents.

There were a couple of interesting views of fatigue as an impairment factor. Despite the findings above it was not seen as a factor worthy of testing for if simple tests were available. Additionally, while it was viewed as the most serious problem responsible for the most productivity loss respondents felt if two similar workers were impaired to an equal degree, it was felt that the fatigued worker could still perform better than one using alcohol/drugs.

One question clearly brought out the suggestion that being 'under the influence of alcohol or illicit drugs' was viewed quite differently from other forms of impairment. 'Zero tolerance' was the view of 81% of respondents for dealing with alcohol in the workplace and 91% of respondents felt the same for illicit drugs. Whereas, fatigue and illness impairment were not viewed to be a problem unless a worker's job could risk others. 30% of the respondents did not view fatigue to be a problem unless the individual could not do their job.

DISCUSSION

As a group, it is estimated that the study participants increased risk of accident by almost 9% solely due to inadequate sleep. If this is projected onto the 1500 workers of the Canada Line project it means higher work risk for all, underperformance and potential productivity loss in a year. It is interesting to note that the Canada Line project was not performing poorly when it comes to accidents. Through the month of August for the year 2007, the project was under industry averages for both frequency and severity of accidents (SNC-Lavalin Inc. 2007). This is not necessarily a contradiction of the findings herein. As reported by Hursh (Hursh, Raslear *et al.* 2006), p6), "… a fatigue model can predict an increase in fatigue-associated risk, not the specific occurrence of an accident. … Wide variations exist in individual sensitivity to the factors that cause fatigue, so, again, fatigue models can only predict

an increased risk of fatigue, not a specific individual person's level of fatigue or performance".

There is also a possible under-statement of the amount of sleep deprivation driving fatigue amongst these workers due to timing of the study. The study spanned 2 months during which there were 2 statutory holidays which added an extra day off to a weekend. The workers wearing the actigraph during these 'long' weekends were able to sleep longer and effectively had another day of sleep debt repayment. This study did not invalidate this data but took it as representative of what would occur naturally over the course of a year.

Table 4: Results of Surveys

	Observation	UK	BC
Seriousness	Alcohol	#2	#2
	Fatigue	#1	#1
	Illicit Drugs	#3	#3
	Illness	#4	#4
	Medicinal Drugs	#5	#5
	Other factors	#6	#6
Prevalence	Alcohol	#3	#3
	Fatigue	#1	#1
	Illicit Drugs	#6	#5
	Illness	#2	#2
	Medicinal Drugs	#5	#4
	Other factors	#4	#6
Problem Priority	Alcohol	#2	#2
	Fatigue	#1	#1
	Illicit Drugs	#4	#3
	Illness	#3	#4
	Medicinal Drugs	#6	#5
	Other factors	#5	#6

In addition, most participants only wore the actigraph for a specific week therefore it is not known whether this one week is truly representative of the weekly average for a year. Different weeks might produce different results for each worker but it is believed the numbers sampled were large enough to help dampen variation from all of these factors. Also, individual sleep habits were not known prior to the week the actigraph was worn meaning that individuals may have come into the study already lacking sleep. The effect of this would be to lower the reported percentage Mental Effectiveness levels.

Interestingly, actual measured sleep did not match self-assessed subjective measures of sleep. The correlation to individuals' logbooks and measured sleep was not strong. This suggests workers don't actually know how long or how well they sleep at a given point and is a flag for researchers relying on individuals' estimates of nightly sleep, even when keeping a logbook.

In terms of understanding fatigue-impairment, it is clearly considered to be a serious factor but it still does not receive the same focus or understanding as others such as alcohol-impairment. Many employers fail to understand that it is their established work schedules that hinder natural work-rest cycles which imports impairment into the workplace where it is neither recognized as a problem nor dealt with effectively. Society still holds too strong a belief that impairment from lack of proper sleep is a

worker's problem more than an organizational problem and further, that it is something that must be tolerated as nothing can be done about it.

Finding that many organizations do not even have impairment policies or tests for impairment suggest that much work is needed in this area. It is troublesome to think that organizations which would release employees immediately for consuming alcohol or illicit drugs at work, would allow an equally impaired worker to continue working simply because they are sleep deprived. This same problem spills over onto the roadways as those same fatigued employees try to drive home. If the estimates of productivity loss are not enough incentive to take more action in this area, the workers' safety alone should be.

Creating worker awareness of sleep requirements and the impact of too little sleep should be undertaken in construction. Many treat sleep or the lack of sleep as a 'fact-of-life' in the 21st century without regard to what it may mean. It can not only increase risk of accidents at home and in the workplace, it can be a factor degrading personal health. In addition, it is considered by some that there is a direct link between fatigue and worker stress, which has not been explored in this research, but worthy of future research. Organizations need to be aware of the potential decrements in performance due to inadequate sleep and promoting individual awareness on this issue and promoting good sleep habits as preventive to losses.

CONCLUSIONS

Although other studies have provided valuable insights into fatigue and its operational influence in numerous other sectors, little was known of the sleep habits of construction workers despite ample reasons for concerns for poor safety records and productivity. Thus this large study in an operational setting attempted to understand whether fatigue might be a factor of concern.

The results of this study indicate an average increase in risk of accident was 9%. For field workers it was even higher (10.1%) and when coupled with a more hazardous work environment in the field should raise the flag on fatigue for construction workers. In addition to other forms of impairment in the workplace the indications are that fatigue-impairment is a serious erosion of personal safety and base productivity.

As no effective screen exists for the presence of excessive fatigue in the workplace, developing one must be a priority for all industries interested in improving safety and productivity. Additionally, it is important to explore what may be done to screen out fatigue-impaired workers who are not fit for working their shift.

Workers need to understand the impact of poor sleep and what they can do in their personal lives to improve their sleep. The construction industry should profile its jobs and ensure that those jobs with highest risk receive a higher priority of training regarding this subject. Mobile equipment operators, shift workers, night workers and workers putting in long hours at the workplace are examples of workers who should be targeted for training, monitoring and rules.

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