Shift work adversely affects human longevity

Shift work has become an indispensable part of today's life. Nearly one-fifth of the total global workforce works in shifts and the population of shift workers is growing steadily[1]. Effects of shift work on the human circadian rhythm are well known[2]. There is persuasive evidence to prove that shift work compromises human health and safety by disrupting the circadian rhythm[1]. It causes several sleep-related and social problems. It retards performance and increases the chance for occurrence of major industrial accidents[1]. Shift work has also been associated with increased risk of clinical complications, such as ischaemic heart disease (IHD) and peptic ulcer[1]. It is generally presumed that it might produce life-shortening effects in humans. However, no evidence exists to reinforce this presumption. In the present study, the null hypothesis that shift work does not produce any adverse effect on human longevity has been tested.

The FoxPro database of the South-Eastern Central Railway (SECR), Nagpur, India, that contained biographical and job-related information on 3912 day workers (DW) and 4623 shift workers (SW) was accessed with permission. The database contained information on the dates of birth/retirement and death of each worker. Data on all-cause mortality of 594 Railway employees (282 DW and 312 SW) over a span of 25 years were used and analysed in the present study. The cause of death was not documented in the database. Retirement age for the workers was 58 years. All the DW (office job: $n = 190$; miscellaneous job: $n = 92$) performed day duty between 09:00 and 18:00 h with lunch break from 13:00 to 14:00 h, whereas the SW (running staff: $n = 163$; gang men: $n = 57$; miscellaneous job: $n = 92$) worked in a rotating system consisting of day shift (08:00–16:00 h), first night shift (16:00–24:00 h) and second night shift (24:00–08:00 h). They worked in each shift continuously for 6 days and had a single-day break before resumption of the next shift. The rotation operated in a clockwise fashion. Majority of the subjects was male. The subjects were only three and one female in DW and SW respectively.

Longevity of each worker was computed from the dates of birth/retirement and death. Per cent mortality was also computed for DW and SW. Both longevity and per cent mortality were plotted as function of work type (Figure 1). CoStat (CoHort Software, version 4.02, ©1990) and Analysis ToolPak (Microsoft Excel) software were used for analysis.

Per cent mortality (all-cause) was more in SW. The results of ANOVA complemented the above findings (Figure 1). A statistically significant reduction in longevity ($P < 0.001$) was noticed in SW (Figure 1). The total longevity reduction amounted to 3.94 years.

There are a number of animal studies that document life-shortening effects of weekly shifting LD cycles, non-24 h LD cycles and continuous light (LL). It has been argued that these effects could be mediated through disruption of the circadian rhythm. The weekly shifting of LD cycles (90° $\Delta\phi_{LD}$) in blowfly, *Phormia terrae novae*[3] and LL or non-24 h LD in fruit fly, *Drosophila melanogaster*[4] negatively modified the lifespan. Subsequently, these findings were complemented by the results of studies involving life-shortening effects of weekly shifting of LD cycles (180° $\Delta\phi_{LD}$) in mouse[5] and hamster[6]. Lighting schedule manipulation has also been reported to produce detrimental effects on the lifespan in several insect species (work of D. Hayes cited in Halberg and Nelson[5]). Surprisingly, till date a few direct attempts have been made to determine if shift work would negatively modify lifespan in humans. However, shift work has been shown to be associated with increased mortality risk[7,8]. In a British study, the authors concluded that 'shift work would appear to have no adverse effect on mortality'. This study was based on the frequency analysis of all-cause mortality in SW, DW and ex-SW[9]. Subsequently in a Danish study[10], it was reported that the relative death risk (adjusted both for age and social class) for SW was 1.1 with a 95% confidence interval between 0.9 and 1.3. In both studies, however, the authors did not compute longevity of the subjects directly. The significance of the findings reported here is that they are based on direct measurement of lifespan in SW and their day-working counterparts, who worked in the same organization.

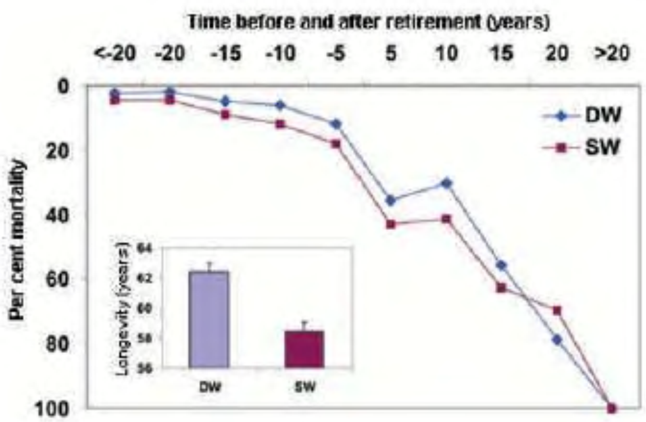

Figure 1. All-cause higher mortality (%) in shift workers. DW, Day workers; SW, shift workers. Work type effect (death before retirement): $F = 25.652$; $df = 1, 4$; $P < 0.007$ (based on two-factor ANOVA). (Inset) Reduction in longevity of SW. SW vs DW: $t = 4.526$; $df = 592$; $P < 0.001$ (based on Student's two-tail t-test). Error bars show +1 standard error.

1. Pati, A. K., Chandrawanshi, A. and Reinberg, A., *Curr. Sci.*, 2001, **81**, 32–52.
2. Edery, I., *Physiol. Genomics*, 2000, **3**, 59–74.
3. Aschoff, J., Saint Paul, U. V. and Wever, R., *Naturwissenschaften*, 1971, **58**, 574.
4. Pittendrigh, C. S. and Minis, D. H., *Proc. Natl. Acad. Sci. USA*, 1972, **69**, 1537–1539.
5. Halberg, F. and Nelson, W., In NIOSH Research Symposium, Shift Work and Health, US Department of Health, Education, and Welfare, NIOSH, Cincinnati, 1976, pp. 13–47.
6. Penev, P. D., Kolker, D. E., Zee, P. C. and Turek, F. W., *AJP – Heart*, 1998, **275**, 2334–2337.

7. Knutsson, A., Hammar, N. and Karlsson, B., *Chronobiol. Int.*, 2004, **21**, 1049–1053.
8. Åkerstedt, T., Kecklund, G. and Johansson, S.-E., *Chronobiol. Int.*, 2004, **21**, 1055–1061.
9. Taylor, P. J. and Pocock, S. J., *Br. J. Ind. Med.*, 1972, **29**, 201–207.
10. Bøggild, H., Suadicani, P., Hein, H. O. and Gyntelberg, F., *Occup. Environ. Med.*, 1999, **56**, 640–645.

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Quantification of trace gas emissions from shifting cultivation areas using remote sensing and ground-based measurements

Shifting cultivation, also known as slash-and-burn cultivation, is widespread in the northeastern region of India and causes ecological loss to the forests and environment. It is locally called as 'jhum' and is practised by indigenous tribes during dry months of February to March every year. In India, 55% of the total forest cover is prone to fires annually[1] and major contribution comes from shifting cultivation. Recurrent forest fires result in loss of forest cover, erosion of topsoil, desertification and decline in forest productivity[2]. Studies reveal that tropical biomass burning is a significant source of organic carbon to the atmosphere[3,4], producing large amounts of trace gases and aerosol particles, which play a pivotal role in tropospheric chemistry and climate[5]. Aerosols containing black carbon are emitted primarily in the tropical and subtropical regions of the world[6], accounting for the release of almost 100 million tons of smoke aerosols into the atmosphere as a result of biomass burning[7]. These submicron smoke aerosols play a major role in radiation balance of the earth–atmospheric system[8], by reflecting a portion of the incoming solar radiation back to space, thereby reducing the amount of sunlight reaching the earth's surface[9,10]. In addition, aerosols from burning serve as cloud-condensation nuclei and alter the properties of the boundary-layer clouds[11]. Due to forest fires, there is widespread concern about the loss of biodiversity, spread of human and plant diseases through colonization, increase in concentration of greenhouse gases, changes on the earth's radiative energy budget, effects on atmospheric chemistry and increase in surface albedo and water run-off.

Biomass burning releases trace gases such as carbon dioxide, methane, nitrous oxide and particles (smoke carbon). In addition, biomass burning perturbs the other components of the earth system, including biogeochemical cycling of nitrogen and carbon (CO_2, CO and CH_4); water run-off and evaporation affecting the hydrological cycle; reflectivity and emissivity of land, which in turn alters the radiative properties of land, and stability of the ecosystems, which in turn impacts biological diversity[12]. Vegetation burning has also been shown to play an important role in annual fluxes of many trace gases to the troposphere and enough evidence exists to show that biomass burning is an important driver of global change[13–15].

Considering the above impacts, information on the location, size, timing of fire, maps of the areas burnt, characterization of fuel and combustion conditions along with the amount of greenhouse gases emitted is required to understand the impact of biomass burning on the atmospheric environment[12,16]. Remote sensing technology, with its multi-temporal, multispectral, repetitive and synoptic coverage, provides valuable information on various fire events in a timely and cost-effective manner. Although the potential of remote sensing technology for biomass burning and fire detection studies is widely recognized, the present regional and global active fire products are widely underutilized by fire managers and their quality needs considerable enhancement, to meet the needs of local user communities[17]. For fire monitoring and burnt area estimation, the general consensus from recent studies is that, data provided by coarse resolution satellites such as NOAA AVHRR at 1 km sensor were of limited use[18]. It was considered to be in general unsuitable to provide reliable estimates of fire activity, especially considering its geographical extent. In case of satellite data with low spatial resolution, fires cannot be accurately assigned to forest or agriculture. Under these circumstances, the data are unreliable for emission estimates. Further, sensitivity to the proportion of pixels that are burnt, i.e. the size and spatial distribution of the burnt areas relative to the sensor spatial resolution, was similarly considered to be a significant factor. Considering these issues due to low spatial resolution of coarse-resolution satellite datasets, evaluation of different sensors with relatively high-to-moderate resolution for burnt-area detection at local scale was considered an area of potential research. In the present study, Indian Remote Sensing Satellite (IRS-P6) – Advanced Wide Field Sensor (AWiFS) temporal data from January to April 2005 covering the northeastern region were used for quantifying greenhouse gas emissions.

Northeast India comprises seven sister states, viz. Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. They are bordered by Bhutan and China in the north, Myanmar in the south and southeast, and Bangladesh in the west. Perennial rivers like the Brahmaputra flow through this region. The Brahmaputra valley is a meeting ground of the temperate east Himalayan flora and the wet evergreen and wet deciduous flora. Major forest types found in the study area are tropical evergreen and semi-evergreen, moist deciduous forest, bamboo brakes, Dipterocarpus, grasslands, riverain, sal, teak, pine, etc.[19]. The tropical vegeta-