Twenty-four-hour pattern in French firemen of lag time response to out-of-hospital cardiac arrest and work-related injury

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Circadian cognitive and physical rhythms plus 24 h patterns of accidents and work-related injuries (WRI) have been verified in numerous studies. However, rarely, if ever, have 24 h temporal differences in both work performance and risk of WRI been assessed in the same group of workers. We explored in a homogenous group of French firemen (FM) 24 h patterns of both lag time (LT) response duration to emergency calls for medical help (ECFM) for life-threatening out-of-hospital cardiac arrests (OHCA), used as a non-specific index of work performance, and WRI. Our studies demonstrate rather high amplitude statistically significant 24 h patterns of the two variables. The LT response duration was twice as long ~0500 h (slowest response) than ~1600 h (fastest response). In the same group of FM, the actual number WRI/h was greatest ~1600 h and lowest in the early morning hours. However, the 24 h pattern of the relative risk (RR) of WRI, i.e., per clock hour number of WRI/total number of responses to emergency calls x number of FM at risk per response), was very different, the RR being greatest ~0200 h and lowest in the afternoon. The 24 h pattern in LT response duration to ECMH for OHCA and RR of WRI was strongly correlated (r=+0.85, P<0.01), with the nocturnal trough (slowest response) in LT response duration coinciding with the nocturnal peak RR of WRI. These findings indicate the requirement for circadian rhythm-based interventions to improve the nocturnal compromised work performance and elevated risk of WRI of shift-working FM.

Keywords: Cardiac arrests, Circadian rhythms, Firemen, Shift work, Work-related injuries, Work performance

Synchronization of biological rhythms to a period (τ) of 24 h is achieved through the interaction of complex endogenous processes of genetic origin and environmental time cues of exogenous origin, such as the day-night, sleep-wake, and in certain conditions food consumption cycles¹. In human beings, the two main environmental synchronizers of endogenous circadian rhythms are the 24 h light-dark and sleep-wake cycles. In this regard, the significance of sleep in the structuring of circadian rhythms² is well demonstrated by sleep-deprivation experiments³, and the importance of light is well established by findings illustrating its importance in managing the human circadian system⁴. Desynchronization of the circadian time organization is expressed by changes in τ from 24 h or alteration relative to clock time of circadian phase (peak and trough times), representing temporal dissociation of the functioning of the timekeeping system from astronomic and social periodic time cues⁵. The origin of circadian desynchronization can be either external — when related to environmental and social factors, e.g., in jet lag⁶ and shift work⁷, or internal — when related to biological factors, e.g., in aging⁸¹¹ and some diseases¹².

Many laboratory and field studies verify human circadian rhythms in cognitive and physical abilities; in diurnally active persons generally they are poorer during the nocturnal span and best in the afternoon-early evening¹³⁻²⁸. In addition, various studies demonstrate day-night differences in the risk during the 24 h of workplace accidents and disasters, road accidents, and work-related injuries (WRI)²⁹⁻³⁷. However, rarely, if ever, have studies simultaneously explored in the same group of workers the impact of

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¹The findings of this study, in part the subject of an oral presentation at the 27th Conference of the International Society for Chronobiology (New Delhi 3-7 October 2012), are dedicated in memoriam to Israel Ashkenazi.
the circadian time organization upon both work performance and WRI.

A continuing research focus of ours is the disruptive effects, relative to the circadian time organization, of permanent night and rotating shift-work schedules, especially upon employees having stressful physical and cognitive duties. Our concern is their potential consequent negative impacts on health, well being, safety, performance, and differential risk during the 24 h of WRI and thus the requirement for chronopreventative-based interventions. Our most recent research has involved firemen (FM) of the Service Départemental d’Incendie et de Secours de Saône et Loire, 71st French Department, “SDIS-71” (Fire and Rescue Services of Saône et Loire) who are continually exposed to difficult and stressful duty while working odd schedules. Based upon past and most recent research findings, it is hypothesized the FM of the SDIS-71 are likely to be prone to dysfunction of the biological time organization, i.e., circadian rhythm desynchronization, showing symptoms such as sleep complaints, fatigue, mood swings, etc., and potentially increased risk of WRI.

Herein, we review findings of still ongoing studies of French FM of the SDIS-71 that establish 24 h patterns of WRI and duration of the lag-time (LT) response to emergency calls for medical help (ECFM) for out-of-hospital cardiac arrest (OHCA), used as a non-specific index of work performance, with the ultimate future aim to propose recommendations, based upon circadian rhythm criteria, to optimize work performance and minimize risk (chronoprevention) of WRI.

Work environment and schedule of FM of the SDIS-71

The work force of the SDIS-71 comprises both intensively trained professional regular FM paid a set salary plus volunteer FM (VFM) paid by the hour. The weekly work schedule of RFM entails one or two night shifts and averages 35 h, thereby respecting the French labor law. However, weekly work hours may be greater than this, depending upon the number and timing of emergency calls and the duration of required operational tasks, since when called for help FM must work until all operations related to a medical, fire-fight, or other emergency are completed and the work site formally declared safe. The work schedule of the VFM, in contrast, is typically weekends, since it is dictated by the requirements of their regular primary employment.

Circadian rhythm of performance of firemen: Duration of the LT of response to calls for medical emergencies

All the main fire stations of the SDIS-71 are staffed around-the-clock by well-trained and fully prepared RFM and VFM. Each incoming telephone communication to the Emergency Call Center (ECC) is time-stamped electronically (min, h, d, mo, and yr). The clock time (min, h, d, mo, and yr) of departure of the service vehicle, i.e., when crossing the threshold of the station gate, in response to the corresponding CFMH is recorded by the radio operator at the ECC. In actuality, the LT response is a group phenomenon, involving FM of both the ECC and responding fire stations and entailing an integration, among other factors, of various cognitive judgments and decisions, such as choice of vehicle type, required number of RFM and/or VFM attendants, last-moment checks of equipment, etc., before departure.

We chose to focus on the duration of the LT response of the SDIS-71 FM to CFMH for OHCA as a sensitive surrogate measure of work performance, since FM are well aware of the response to this life-threatening event and must always be as rapid as feasible, independent of time of day. The accessible 4 yr database (January 2005 to December 2008) of the SDIS-71 revealed a total of 639 ECC for OHCA; however, only 568 met the qualification for analysis, i.e., contained the full complement of required data. The criteria for validity of each LT report were absence of missing data for any of the recorded items plus the LT being neither 0 nor >18 min (3-fold the mean LT response by the SDIS-71 FM to all emergency calls during the 4 yr span). ECC/h for urgent medical aid displayed two peaks, ~1000 h and ~1700 h, respectively, with ~60% of the CFMH for OHCA. Extensive research shows the occurrence of myocardial infarction and other acute cardiovascular events, including hemorrhagic and ischemic stroke, of diurnally active persons is greatest in the morning, ~1000 h. Thus, the morning time peak of CFMH and corresponding peak in the number of departing vehicles from fire stations during the 24 h are believed to be indicative, in large part, of the day-night pattern of cardiac and cerebrovascular accidents in the population served by the SDIS-71.

The duration of the LT response of FM responding to the life-threatening medical emergency of OHCA varied significantly during the 24 h, with the response being on average twice as long ~0500 h, when
slowest, than at ~1600 h, when fastest. This finding is in close agreement with the results of various laboratory and industrial studies cited above generally showing poorest performance of diurnally active individuals nocturnally (~0300–0500 h) and best performance in the afternoon (~1500–1700 h).

**WRI of SDIS-71 firemen**

The major aim of this aspect of investigation was to explore 24 h patterns of WRI experienced by FM of the SDIS-71. When experiencing a WRI of any severity, even minor abrasions and insect bites, the policy of the SDIS-71 requires FM to consult with the medical department for examination and documentation that is summarized using a standardized medical report. Each report contains the circumstances, e.g., operational duties, nature and severity of the WRI, and details, including its clock time and calendar date. The 4 yr database of the SDIS-71 revealed a total of 187 WRI, corresponding to a rate of ~0.03 WRI/FM, which is somewhat lower than the estimated rate of ~0.049 WRI/FM for non-lost-time WRI reported for all FM of the United States. The disparity between the WRI rate for FM of the SDIS-71 and other fire services most likely is representative of the differential exposure to high-risk emergencies. For example, ~67% of the services provided by the FM of the SDIS-71 consists of responses to CFMH that are associated with low risk of WRI, and only ~13% of them consists of calls for fire fighting (CFFF) that are associated with high risk of WRI. Other factors include differences of training, administrative policies, and threshold criteria for the report and conformation of WRI.

The actual number WRI/h exhibited a statistically significant 24 h pattern that peaked at 1600 h; a pattern that was similar from year to year and season to season (winter and summer). However, since the number of responses by FM to emergencies varied according to clock hour, the proper manner of analyzing the WRI data is in terms of relative risk (RR) per clock hour calculated as: number of WRI/total number of responses to emergency calls x number of FM at risk per response.

The 24 h pattern in the RR of WRI differed greatly from that of the actual number of WRI. The peak RR of WRI was ~0200 h, with the RR of WRI being ~2-fold greater nocturnally than in the morning and afternoon. Although the differential distribution during the day and night of the various types of ECC could conceivably explain the detected 24 h pattern in WRI and their RR, this does not seem probable. Analysis of the 4 yr ECC data reveals: (i) calls for OHCA and other cardiac emergencies were most numerous in the morning (0600-1200 h); (ii) CFMH of all kinds were most frequent ~1700 h (least frequent ~0300 h); and (iii) CFFF, the highest risk duty of FM, were greatest in number ~2200 h (lowest in number ~0500 h). Even though the peak in CFFF is ~2200 h, it is nonetheless conceivable that some WRI could be associated with extended fire fighting operational duty. Because CFFF often entails sustained work, any associated WRI after many hours of fire fighting might contribute to the 0200 h peak of WRI relative risk. However, even if this is the case, the WRI occurring at this time of day, at least in part, could be a consequence of circadian rhythm–dependent decreased cognitive and physical abilities, e.g., slowed decision-making, slowed reaction time, etc. and reduced coordination, strength, and stamina, as verified by numerous circadian rhythm laboratory and field studies cited above, in addition to the accumulated fatigue stemming from both prolonged fire fighting and atypical work schedule. We feel the potential contribution of such fire fighting-related WRI, per se, to the 0200 h peak of the 24 h pattern in the RR of WRI is likely to be minor, since CFFF made up only ~13% (i.e., 1 of every ~8) of all overall ECC for the 4 yr database analyzed.

**Conclusion**

To the best of our knowledge, the above reported research findings constitute the first attempt to assess in the same working population of FM both work performance, i.e., duration of the LT response to ECMH for OHCA, and the RR of WRI. Collectively, the findings are consistent with the hypothesis the 24 h pattern in the RR of WRI is not simply dependent on the distribution during the night and day of high-risk duties, workload, or accumulated work-related fatigue during duty, but that it is, to an important extent, a consequence of circadian rhythms of human cognitive and physical performance capabilities as collectively integrated into and represented by the LT measure. The nocturnal peak in the duration of LT (slowest response) coincides with peak RR of WRI. Indeed, the 24 h profiles of the LT response to ECMH for OHCA and RR of WRI are strongly correlated (r=+0.85, P<0.01). Moreover, the finding that the 24 h pattern in the RR of WRI is stable from year to year as well as season to season also is consistent with this hypothesis.
It is believed that these findings will help build the bridge between two potentially related and parallel phenomena: the 24 h pattern of the duration of the LT response to ECMH for OHCA, used as global, albeit, non-specific measure of work performance, which in diurnally active FM is ~2-fold slower during the nighttime than daytime, and the RR of WRIs, which also is ~2-fold greater during the nighttime (0200 h) than late morning and mid-afternoon. Our ongoing research on the same SDIS-71 FM is currently examining, among other aspects, the effect of shift-work schedule and strenuous work demands on circadian synchronization plus individual differences in work performance as background to conceptualizing and testing potentially innovative chronopreventative strategies aimed at protecting the health, well-being, safety, and performance improvement of shift-working FM.

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