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LIGHT EXPOSURE OF WORKERS IN DIFFERENT OCCUPATIONS

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Abstract

Twenty-four hours light exposure of employees in three different occupations was assessed for a working week during both summer and winter. Occupations being exposed to light at night and those exposed to low daytime light levels were represented by night shift working geriatric nurses and daytime working hotel staff, respectively. Their light exposure was compared to the light exposure of outdoor workers represented by refuse collectors. In winter, luminous exposure of night shift working geriatric nurses and daytime working hotel staff amounts to only 2 % and 12 % of the luminous exposure of outdoor workers, respectively. In summer, the respective values are 6 % and 21 %. This could lead to a desynchronization of circadian physiological processes in the human body.

Keywords: personal light exposure, workers, occupation, illuminance, luminous exposure

1 Introduction

Light – both natural daylight and light from artificial lighting sources – is the critical stimulus for synchronizing circadian physiological processes in the human body to the natural day-and-night rhythm. Light exposure at night (e.g. during night shifts) as well as reduced daytime light levels (caused by predominantly indoor activities and too little time spent outdoors during the day) contribute to circadian desynchronization of these processes. The desynchronization, in turn, has been associated with increased risk of health problems (such as cardiovascular diseases, metabolic abnormalities, cancer and depression), impaired cognitive performance or increased anxiety (Foster, 2020; NTP, 2021).

Research on personal light exposures in field studies is of importance to gain better understanding of a possible connection between light exposure and health risks. In an ongoing field study, we examine light exposure of various occupations for which we assume different 24-hour light exposure profiles and levels: employees working in night shifts and being therefore exposed to light at night, those supposed to experience low levels of light exposure during the day while spending much of their working time indoors, as well as outdoor workers. Here we present the results on light exposure of night shift working geriatric nurses (“light-at-night” workers), daytime working hotel staff (“lack-of-light” workers) and refuse collectors (outdoor workers). The light exposure is described as illuminance E_v and luminous exposure H_v (illuminance × exposure duration).

2 Methods

Night shift working geriatric nurses, daytime working hotel staff and refuse collectors were recruited in Dortmund, Germany (51,5 °N). The study participants recorded personal light exposure continuously for a working week in winter (February 4 to February 12, 2020) and in summer (June 2 to June 9, or June 20 to June 28, 2020). Light exposure was assessed during all daytime activities using a commercial actimetry device ActTrust (ActTrust, 2017) attached on the outer layer of clothing at chest level (Figure 1) and recorded every 30 s. Before the devices were used in the field study, they were calibrated in the optical laboratory of the Federal Institute for Occupational Safety and Health (Udovicic et al. 2016).

Figure 1 – An ActTrust device (Condor Instruments) in a badge case placed at chest level on the outermost layer of clothing.

When in bed to sleep, the participants were instructed to place the devices on the bedside table in order to measure bedroom light levels. Therefore, the collected data contain the 24-hour light exposure from natural and artificial light sources. The interpretation of light exposure data was supported by an activity diary recording the periods of indoor (at the workplace, at home) or outdoor time (at the workplace, during commuting to work, doing sports). Since the ActTrust devices also contain accelerometers to detect activity, light exposure data of time ranges when the device has not been worn could be excluded.

Before the first data collection, participants were informed about the goal of the study. They provided written consent, were completely free to withdraw at any time, and received financial compensation for participating in the study. The data were stored and processed anonymously. The ethics committee of the Federal Institute for Occupational Safety and Health has given a positive vote for the study.

All participants worked full-time. Night shift working geriatric nurses worked in 10-hour shifts starting at 20:00, daytime working hotel staff worked in 8-hour shifts starting at 7:00, and refuse collectors worked in 8-hour shifts starting in winter at 7:00 and in summer at 6:30.

The measured illuminance E_{v} was averaged over one hour, in order to obtain 24 hourly values. For example, the average hourly illuminance between 13:00 and 14:00 is assigned to 13:30. Before further analysis the average hourly illuminances for each working day were $\log_{10}$-transformed to meet the requirements for a normal distribution. All available working days for a specific occupation and season were combined in order to obtain the respective average hourly illuminance $\bar{E}_{\mathrm{v}}$. The occupation, the number of participants and the number of available working days in winter and summer are shown in Table 1.

Table 1 – Number of participants and averaged working days in winter and summer.

Occupation	Season	Number of participants	Number of working days
Night shift working geriatric nurses	Winter	4	13*
	Summer	6	17*
Daytime working hotel staff	Winter	5	20
	Summer	3	9
Outdoor working refuse collectors	Winter	6	13
	Summer	3	6

* Night shift working days between a previous and a subsequent night shift.

3 Results

The average hourly illuminances $\bar{E}_v$ measured over 24 h in winter and in summer 2020 by night shift working geriatric nurses, daytime working hotel staff and outdoor working refuse collectors are shown in Figures 2, 3 and 4, respectively.

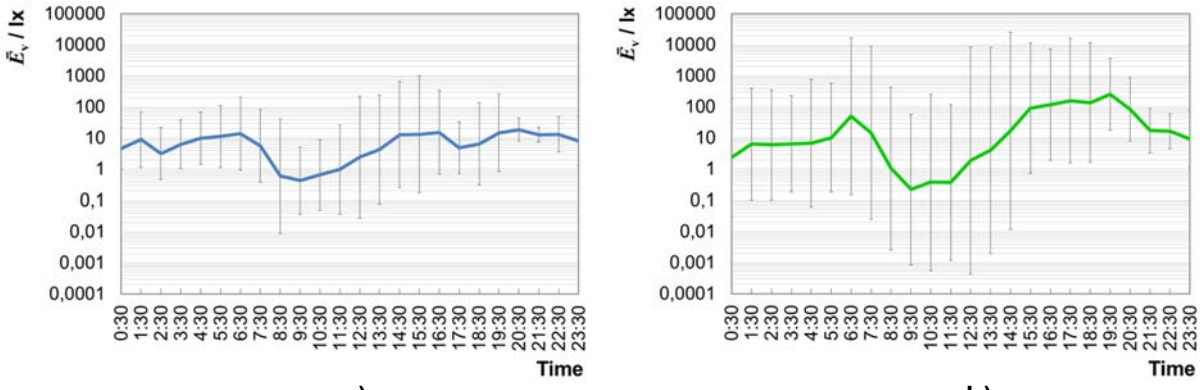

Figure 2 – Night shift working geriatric nurses: average hourly illuminances $\bar{E}_v$ and 95 % confidence intervals for log-transformed data in winter (a) and in summer (b).

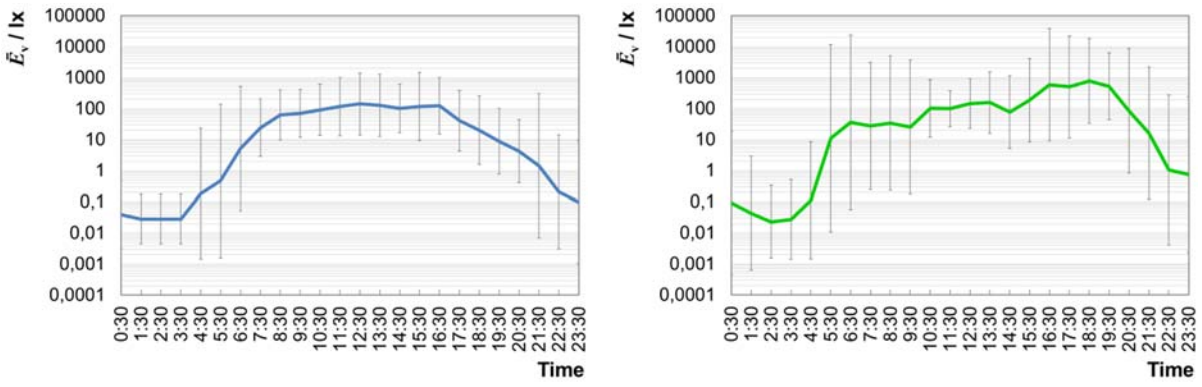

Figure 3 – Daytime working hotel staff: average hourly illuminances $\bar{E}_v$ and 95 % confidence intervals for log-transformed data in winter (a) and in summer (b).

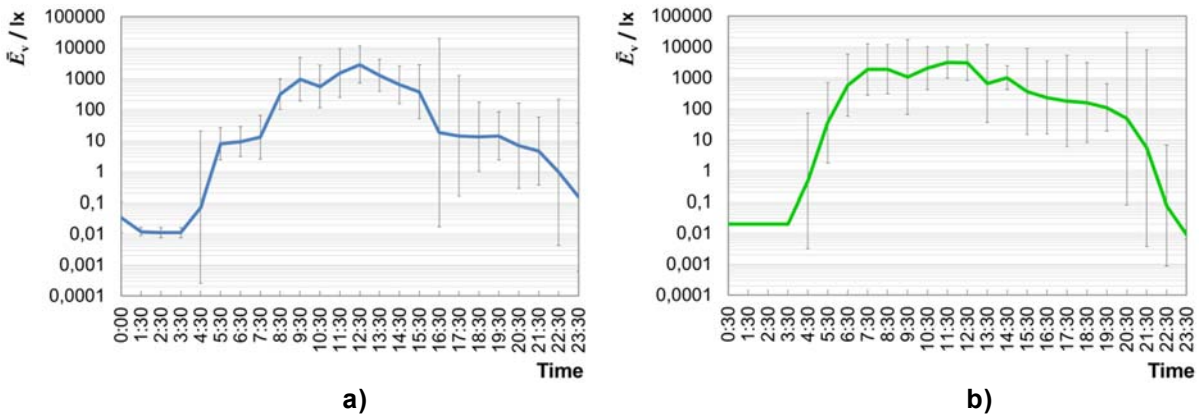

Figure 4 – Refuse collectors (outdoor workers): average hourly illuminances $\bar{E}_v$ and 95 % confidence intervals for log-transformed data in winter (a) and in summer (b).

The 24-hour light exposure profile of night shift working geriatric nurses shows in summer two maxima, one in the early morning at 6:30, when the participants were on their way home, and the second in the early evening at 19:30, during their journey to the workplace. The average

hourly illuminance is in summer at 6:30 50 lx, and at 19:30 253 lx. The low average hourly illuminance is further exacerbated in wintertime due to short day lengths, barely exceeding a value of 15 lx.

The light exposure profile of daytime working hotel staff in summer shows higher light exposures during lunch breaks and / or after working hours in the afternoon. A longer photoperiod in summer obviously leads to an increased exposure to daylight. In summer afternoon there are two maxima, one at 16:30 (590 lx) and the second at 18:30 (790 lx). The average hourly illuminance in winter at 12:30 amounts to 143 lx and at 16:30 123 lx.

As expected, outdoor working refuse collectors were exposed to much higher light levels during working hours than the other two occupational groups. The average hourly illuminance at 12:30 in winter is 2 850 lx, in summer 3 100 lx.

Based on the average hourly illuminance $\bar{E}_{\mathrm{v}}$, the luminous exposure H_{v} in winter and in summer was calculated. Table 2 shows that, compared to outdoor working refuse collectors, night shift working geriatric nurses and daytime working hotel staff in winter get only 2,2 % and 12,4 % of the luminous exposure, respectively. The corresponding values in summer are 6,1 % and 20,7 %, respectively.

Table 2 – Luminous exposure H_{v} of geriatric nurses, hotel staff and refuse collectors in winter and summer.

Occupation	Season	Luminous exposure H_{v} / lx·h	Percent of H_{v} of outdoor workers in respective season
Night shift working geriatric nurses – light at night	Winter	193	2,2 %
	Summer	1 015	6,1 %
Daytime working hotel staff – low daytime light levels	Winter	1 063	12,4 %
	Summer	3 417	20,7 %
Outdoor working refuse collectors	Winter	8 593	100 %
	Summer	16 520	100 %

4 Conclusion

Average hourly illuminances of night shift working geriatric nurses and daytime working hotel staff we report are, compared with those of outdoor working refuse collectors, very low. By the nature of their job, both hotel staff and geriatric nurses spend most of their working time indoors. Being outdoors and exposed to daylight is mostly associated with commuting to work and possibly during lunch breaks. Additionally, geriatric nurses in our study worked 10-hours night shifts. Furthermore, night shift workers sleep during the day and invariably can experience only short periods of daylight, especially in winter.

The luminous exposure of daytime working hotel staff in winter and summer amounts to 12 % and 21 % of the luminous exposure of outdoor working refuse collectors, respectively. The luminous exposure of night shift working geriatric nurses was only 2 % and 6 % of the luminous exposure of refuse collectors in winter and summer, respectively. Both low daytime light exposure and light exposure at night during night shifts could cause desynchronization of circadian physiological processes in the human body.

Concerning the characteristic features of the light exposure profiles – except for outdoor workers – the results of Rabstein et al. (2019) and Udovicic et al. (2020) are confirmed. These studies examined 24-hour light exposure patterns of shift working nurses and showed that light exposure on working days is essentially determined by the working hours and reaches its maximum during the journey to and from the workplace, provided these commuting times include exposure to daylight. Light exposure profiles of night shift working geriatric nurses, showing two maxima, coincide with those of night shift working nurses. Light exposure profiles of daytime working hotel staff resemble the profiles of nurses working early shift (6:30 to

14:30), too, with the highest light exposures after work (on the way home, while doing shopping, etc.) and in the afternoon (leisure activities).

Illuminance values cannot be compared with those of Rabstein et al. (2019) since they reported blue-light irradiance only. Udovicic et al. (2020) reported maximum average hourly illuminance for night shift working nurses of approximately 50 lx in winter and 900 lx in summer. In case of nurses working early shift, maximum average hourly illuminance was approximately 200 lx in winter and 1 600 lx in summer. However, the illuminance data in Udovicic et al. (2020) were not log-transformed.

Smolders et al. (2013) also reported low illuminance levels for office workers and students from Eindhoven (51,5 °N). The study included measurements of the light exposure at all seasons. Illuminance levels above 1000 lx were found to be relatively rare and the study participants were exposed to illuminance levels below 500 lx for the majority of their day.

Crowley et al. (2015) assessed the 24-hour light exposure patterns of full-time office workers in Chicago (41,9 °N) during a week in summer and winter. The light exposure patterns of office workers at working days in summer are similar to those of day working hotel employees in our study measured in the same season: the average hourly illuminance reaches at most 1 000 lx. However, while the average hourly illuminance of office workers in winter still reaches approximately 700 lx, in case of day working hotel employees in our study its maximum value is much lower and amounts to only 143 lx (see above).

In our ongoing field study, light exposure of a number of other occupations will be assessed by the end of 2022. In future evaluations, the circadian effective light exposure will be described as melanopic equivalent daylight illuminance according to CIE (2018) and analysed taking into account the new recommendations by Brown et al. (2021).

References

ACTTRUST 2017. ActTrust Condor Instruments https://www.condorinst.com.br/en/acttrust-actigrafo/

BROWN, T. M.; Brainard, G. C.; Cajochen, C.; Czeisler, C. A.; Hanifin, J. P.; Lockley, S. W.; Lucas, R. J.; Münch, M.; O'Hagan, J. B.; Peirson, S. N.; Price, L. L. A.; Roenneberg, T.; Schlangen, L. J. M.; Skene, D. J.; Spitschan, M.; Vetter, C.; Zee, P. C.; Wright Jr., K. P. 2021. Recommendations for healthy daytime, evening, and night-time indoor light exposure, *to be published*

CIE 2018. CIE S 026:2018. CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light. CIE Central Bureau, Vienna

CROWLEY, S.J.; Molina, T.A.; Burgess, H.J. 2015. A Week in the Life of Full-Time Office Workers: Work Day and Weekend Light Exposure in Summer and Winter, *Appl. Ergon.* 46 Pt A, 193-200.

FOSTER, R.G. 2020. Sleep, circadian rhythms and health. *Interface Focus* 10: 20190098.

NTP 2021. National Toxicology Program. NTP Cancer Hazard Assessment Report on Night Shift Work and Light at Night. https://ntp.niehs.nih.gov/ntp/results/pubs/cancer_assessment/lanfinal20210400_508.pdf

RABSTEN, S.; Burek, K.; Lehnert, M.; Beine, A.; Vetter, C.; Harth, V.; Putzke, S.; Kantermann, T.; Walther, J.; Wang-Sattler, R.; Pallapies, D., Brüning, T.; Behrens, T. 2019. Differences in twenty-four-hour profiles of blue-light exposure between day and night shifts in female medical staff. *Sci. Total Environ.* 653, 1025-1033

SMOLDERS, K.; De Kort, Y.; van den Berg, S. 2013. Daytime light exposure and feelings of vitality: Results of a field study during regular weekdays. *J. Environ. Psychol.* 36, 270-279

UDOVICIC, L.; Janßen, M.; Nowack, D.; Price, L.L.A. 2016. Personenbezogene Licht-expositionsmessungen in Feldstudien – Eine Handlungsanleitung zur Charakterisierung und Kalibrierung von Lichtexpositionsdetektoren, Bundesanstalt für Arbeitsschutz und

Arbeitsmedizin, Dortmund
https://www.baua.de/DE/Angebote/Publikationen/Berichte/F2355.pdf?__blob=publicationFile&v=5

UDOVICIC, L.; Price, L.L.A.; Khazova, M. 2020. Lichtexposition aus natürlichen und künstlichen Quellen im Hinblick auf circadiane Wirkungen bei schichtarbeitenden Krankenpflegekräften, Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, Dortmund (2020)
https://www.baua.de/DE/Angebote/Publikationen/Berichte/F2355-2.pdf?__blob=publicationFile&v=9