Original article

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Epidemiological research on working hours and health has increased, but the findings are surprisingly inconsistent. Most previous studies have used questionnaire or interview-based data on working hours, which provide only crude information on the exposure to working hours. In this methodological paper, we present and evaluate objective register-based algorithms for assessment of working time patterns for epidemiologic studies

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Developing register-based measures for assessment of working time patterns for epidemiologic studies

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Objectives   Epidemiological studies suggest that long working hours and shift work may increase the risk of chronic diseases, but the "toxic" elements remain unclear due to crude assessment of working time patterns based on self-reports. In this methodological paper, we present and evaluate objective register-based algorithms for assessment of working time patterns and validate a method to retrieve standard payroll data on working hours from the employer electronic records.

Methods   Detailed working hour records from employers' registers were obtained for 12 391 nurses and physicians, a total 14.5 million separate work shifts from 2008–2013. We examined the quality and validity of the obtained register data and designed 29 algorithms characterizing four potentially health-relevant working time patterns: (i) length of the working hours; (ii) time of the day; (iii) shift intensity; and (iv) social aspects of the working hours.

Results   The collection of the company-based register data was feasible and the retrieved data matched with the originally published shift plans. The transferred working time records included <0.01% missing data. Two percent were duplicates that could be easily removed. The 29 variables of working time patterns, generated for each year, were stable across the follow-up (year-to-year correlation coefficients from r=0.7–0.9 for 23 variables), their distributions were as expected, and correlations of the variables within the four main dimensions of working hours were plausible.

Conclusion   The developed method and algorithms allow a detailed characterization of four main dimensions of working time patterns potentially relevant for health. We recommend this method for future large-scale epidemiological studies.

Key terms   method, exposure assessment, working time, shift work, long working hours, health, epidemiological studies

Working time patterns have been a public health issue for over a century. At first, the focus was on night/shift work, which was considered potentially harmful to health. In the 1920s, night work was banned for women in several European countries based on an early International Labour Organization (ILO) convention (1). In 2007, the International Agency of Research on Cancer classified shift work as "probably carcinogenic to humans" (Group 2A) (2), increasing the scientific debate of the possible risks of night shift work (3–6). Circadian disruption caused by working at night has been found to be associated with occupational accidents (7), cardiovascular diseases (8–10), and peptic ulcer (11). Shift work may also be related to type 2 diabetes (12), rheumatoid arthritis (13), multiple sclerosis (14), and psoriasis (15). Currently, the scientific debate of the

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possible health risks related to working time patterns covers the length of working hours and its social dimensions. Extensively long working hours appear to be a risk factor for coronary heart disease, type 2 diabetes, depression, sleep disturbances, and occupational and traffic safety (7, 16–18), and irregular and "unsocial" working hours have been associated with work–life imbalance, work stress, and mental disorders (19–21).

Epidemiological research on working hours and health has increased rapidly but the findings have been surprisingly inconsistent. Most previous studies have used questionnaire or interview-based data on working hours, which provide only crude information on the exposure to the multidimensional aspects of working hours and are additionally based on subjective reporting (3–6, 22–25). The specific measures used vary considerably between the studies, making exposure measurement an important source of bias also for systematic reviews (5). To date, very few studies have utilized daily registry data on working time patterns for exposure information. Lie et al's (26) nested case–control study used national registers to categorize exposure to night work (information on night work was based on the Norwegian Board of Health's registry of nurses and census data), but this study was based on assumptions that may not always hold, such as "work sites other than infirmaries only involved daytime work", whereas "all work at infirmaries was assumed to include night work, except for managerial jobs, teaching, and work at physiotherapy or out-patients' departments". Some observational studies have used company records (27, 28) to categorize workers into day and shift workers. Taylor and Pocock et al (28), for example, defined shift workers as following a system of working hours other than regular day work (eg, 3-shift rotas at weekly or more frequent rotation, alternate day and shift work, double days, rotating 12-hour shift, regular night work). Further measures to characterize exposure to shift work include the use of job titles or a job exposure matrix (29). These methods have been criticized as being biased (30); in addition, information on job title or job exposure matrix cannot characterize multidimensional exposure.

In the National Longitudinal Survey of Youth (31), exposure to different work shifts based on information from both questionnaires and interviews did not match. Questionnaire measurement of the exposure to shift work may result in misclassifications that, if non-differential, reduce the estimated risk towards the null. Findings from the Million Women Study showed that the demographic characteristics of shift and day workers differed (32). This may lead to "differential" misclassification, which can bias results in either direction. Selection bias is possible, for example, if night workers were more difficult to reach by questionnaire or interview than day workers. Reverse causation bias will occur if women with breast

cancer recall and report more accurately their lifetime exposure to night work than healthy women (5). A healthy worker effect and lower response rates in surveys of employees in "unsocial" working hours, in turn, can increase the risk for differential exposure misclassification in case-control studies (33).

To reduce various biases in epidemiological studies on working time and health, it is crucial to develop more accurate and reproducible exposure variables (30, 34–37). Such assessments would also increase opportunities to identify unhealthy components of working time patterns associated with long working hours and shift work. Accordingly, the aim of this study was to design a wide range of objective algorithms to measure and analyze working time patterns in epidemiologic studies that use register-based exposure assessment of working hours. The use of objective, register-based exposure assessment methods we develop in this study could be used to clarify the effects of shift work on chronic diseases in future studies. In addition, we validate a method to retrieve standard payroll data on working hours from the employer electronic records.

Methods

Participants

The individual-level data were collected from employers' electronic working time records from six hospitals participating in the Finnish Public Sector study (38). Total data included 12 391 employees, ranging from 7836–8096 individuals per year and a total of 14 488 274 work shifts (table 1).

To evaluate the annual distributions of worktime characteristics, we limited the data to employees with a work contract of ≥10 months and ≥150 working days a year and excluded small groups not belonging to either nursing personnel or physicians (N=191 in 2013) based on their work contract data. The final analytical sample for comparisons between the study years included 7643 participants varying from 4808–4967 participants per year (tables 3–6). They covered 10 235 267 work shifts. The hospital districts gave a written permission to the Finnish Institute of Occupational Health to use the employers' registry data on working hours for scientific research. All data were anonymized for research purposes. The ethics committee of the Hospital District of Helsinki and Uusimaa approved the Finnish Public Sector Study.

Working time data

All payroll-based daily working hour data were retrieved using the shift scheduling program Titania® from the

Table 1. Characteristics of the total data by follow-up year. [SD=standard deviation.]

Characteristic	2008 (N=8052)				2009 (N=7936)				2010 (N=7848)				2011 (N=8096)				2012 (N=8044)				2013 (N=8039)			
	Mean	SD	%	N	Mean	SD	%	N	Mean	SD	%	N	Mean	SD	%	N	Mean	SD	%	N	Mean	SD	%	N
Age	42	12			42	12			42	12			42	12			43	12			43	12		
Men			13				13				13				14				14				15	
Part-time work			15				15				16				17				17				16	
Work time contract																								
Nursing (shift work)			52				51				51				51				51				51	
Nursing (day work)			33				33				32				31				31				31	
Physician			12				13				13				13				13				13	
General			1				1				0				0				0				0	
Regular (37 hour/week)			1				2				1				1				1				1	
Variable (average 37 hour/week)			1				0				2				3				2				2	
Length of work contract/ year																								
≤30 days (≤1 month)			5				4				3				4				4				4	
31–60 days / (1–2 months)			4				3				4				4				3				3	
60–150 days / (2–5 months)			11				10				11				11				10				10	
150–299 days / (5–10 months)			10				10				9				9				9				9	
≥300 days / (>10 months)			71				73				73				72				74				74	
Most frequent occupational titles																								
Nurse				2563				2595				2610				2708				2753				2770
Ward domestic				673				638				649				630				596				579
Practical nurse				573				495				497				468				274				215
Departmental secretary				508				513				502				524				525				506

beginning of 2008 to the end of 2013. The working time data were based on the shift plans (rotas) that were made with Titania® (CGI Finland) for every 3 or 6-week-period. Titania® is a Windows-compatible software which is used for shift planning and payroll in the majority of public sector organizations in Finland. It has tools for the planning of working hours according to national legislation and collective agreements with labor market organizations. The software calculates employee's monthly reimbursements based on the materialized working hours and is linked to the electronic time card systems to correct the planned working hours by the individually punched true hours on minute-by-minute bases. The rotas are checked by the superiors of the organizations before acceptance for payroll and filed for ten years according to Finnish legislation

The sampling software (by CGI Finland) was used to retrieve all the data from the saved rotas. The resulted data included the starting and ending times of the daily working hours and the reasons for an absence (day off, sick leave, maternity leave, physician's on-call duties, annual leave etc). Each individual work shift was also linked to numerous background information including the unique personal identification code ID (with information on age and sex), occupational title, working time contract/shift system, work unit, and shift rota unit.

To classify work shifts based on the shift starting and ending times, the sampling software scored the working hours into the following shift types: early morning shift (starts before 06:00 hours and is not categorized as a night shift); morning shift (starts 06:00–07:00 hours); day shift (starts after 07:00 hours and ends no later than 18:00 hours); evening shift (starts after 12:00 hours and is not categorized as a night shift); night shift (≥3 hours between 23:00–06:00 hours, according to the Finnish working time law).

Analysis of data quality

The process of data cleaning involved raw data analysis, definition, and verification of data transformation workflow, mapping rules, and the handling of possible errors (39). The quality of the retrieved total working hour data was examined by using the main lines of data taxonomy developed for time-oriented data (40). Based on the analysis we excluded all duplicates and missing data. The correctness of the data was additionally verified by comparing randomly selected consequent 3-week shift plans of one psychiatric inpatient department (with 15 employees), one acute inpatient department (with 22 employees), and one outpatient ward of home care (with 36 employees) to the data retrieved day-to-day and on individual basis. This assessment was done by comparing the scoring of work shifts obtained from the sampling software with the shifts based on the original raw data.

Dimensions and variables characterizing working time patterns

Based on the literature (see discussion for reasoning and justification), we constructed 29 annual variables of working time patterns (table 2). These variables belonged to four major working-hour domains: (i) the length of the working hours, including seven variables describing annual, weekly or daily working hours calculated for each year; (ii) time of the day (shift work), including six variables that were used to measure the proportion of different shifts; (iii) shift intensity, including seven variables related to both the consecutive work shifts and recovery time between the shifts; and (iv) social aspects of the working hours, including nine variables related to the distribution of free days, irregularity and predictability of the working hours, and worktime control.

Statistical analysis

Although the working-hour records are used for payroll purposes and should be precise, we examined whether the retrieved data and the created working time variables were correct and meaningful by calculating the distributions (mean, median, min and max) of these variables for each year in the final analytical sample. This helped to detect possible outliers and analyze the external validity of the data. Two statisticians calculated the working time variables from the original retrieved ASCII data using different statistical packages (Stata and SAS) to double-check the used formulas for calculating the variables. Based on the annual distributions, we investigated the prevalence of the working time variables in 2013 by calculating the proportion of those having (i) at least once a year, (ii) ≥10%, (iii) ≥25%, or (iv) ≥50% of the annual occurrence of the working time variables. The stability of the data between subsequent years was studied by calculating pairwise correlation coefficients of the repeated data on the working hour characteristics among those with ≥10 months of work contract and ≥150 working days during both subsequent years for all year-to-year combinations. We averaged the correlation coefficients for the combinations within 2-, 3-, 4- and 5-year periods. For example, the mean was calculated over the coefficients including year to year pairs for 4-year periods: 2008–2011, 2009–2012, and 2010–2013. Furthermore, we investigated the interrelationships between the working time variables by calculating the correlation coefficients for annual working time pattern variables (that were described in proportions) within the four working time domains.

Results

Quality control

In the original raw data from the 12 392 participants, including 14 488 274 work shifts in 2192 separate days from the time period 1 January 2008 to 31 December 2013, there were no missing values in shift starting or ending times. Only 189 participants had incomplete data and one had a missing ID code. There was a small amount of redundant duplicates (26 308 shifts, <0.01% of the shifts) due to the same employee being recorded twice in the same rota. The redundant duplicates were removed. A larger amount of shifts (1.8%) were incorrect duplicates having some differences in some of the variables for the same day of the same participant. The most frequent reasons for the wrong duplicates were (i) different rota number but otherwise identical shift data due to the employee being at the same time in two separate rotas; the second duplicate was removed; (ii) two separate shift starting and/or ending times very close to each other (eg, 08:00–16:00 and 08:00–16:15 or 08:00–16:15 and 08:15–16:15 hours). This error could occur due to after-shift corrections to the starting or ending times for salary corrections; the earlier starting and/or later ending times were kept and the shorter work shift was removed; (iii) having both a free day and a work shift overlapping with each other that could be because of last-minute cancelling of a free-day. In that case, the work shift was kept and the free day was removed. There were no outdated data (shifts outside the analyzed years).

The comparison of the six randomly selected 3-week shift plans from three different inwards showed a complete match between the original on-wall Excel rotas of the hospital departments and the retrieved Titania® registry data for shift starting and ending times, shift types, and absences from work.

Frequency and distributions of working time variables

The descriptive statistics of the created working time characteristics in 2013 are shown in table 3 according to the main occupational group and worktime contract. We found no unexpected distributions, based on our earlier knowledge and analysis of the working hours of the same or similar organizations (41, 42) and discussions with the persons responsible for the shift planning of the organizations. Among nursing personnel, the mean of the average weekly working hours during a year (when all calendar weeks with any work were included and both paid leave – eg, sickness absence – and unpaid leave were excluded) was 34.9 hours in day work and 34.7 hours in shift work among the nursing personnel. Among the physicians, the average weekly

Table 2. Description of 29 variables characterizing four dimensions of working time patterns.

Working time dimension/variable	Description
Length of working hours	
Weekly working hours	The average weekly (from Monday 00:00 to Sunday 24:00) working hours during the year. Calendar weeks without any work, that is on paid or non-paid leave, were excluded
% of long (>40 hours) working weeks	Proportion (%) of long working weeks: the proportion of calendar weeks of >40 weekly hours of all calendar weeks with work during the year
% of long (>48 hours) working weeks	Proportion (%) of long working weeks: the proportion of calendar weeks of >48 weekly hours of all calendar weeks with work during the year
Shift length (hours)	The average length of all shifts during the year in hours
% of long shifts	Proportion (%) of ≥12 hours shifts/all shifts during the year
Length of night shifts (hours)	The average length of all night shifts (subjects without night shifts excluded) during the year
% of long night shifts	Proportion (%) of ≥12-hour night shifts/all shifts during the year
Time of the day	
% of early morning shifts	Proportion (%) of early morning shifts /all shifts during the year
% of morning shifts	Proportion (%) of morning shifts /all shifts during the year
% of day shifts	Proportion (%) of day shifts /all shifts during the year
% of evening shifts	Proportion (%) of evening shifts /all shifts during the year
% of night shifts	Proportion (%) of night shifts /all shifts during the year
% of non-day shifts	Proportion (%) of non-day shifts (=early morning, evening, or night shifts)/all shifts during the year
Shift intensity	
No of consecutive working days	The average number of consecutive daily work shifts (without free days) during the year (starting from and ending to a free day or other absence from work)
% of long spells of work shifts	Proportion (%) of >6 consecutive daily work shifts (without free days)/ all spells of consecutive daily work shifts)
No of consecutive night shifts	The average number of consecutive night shifts during the year (subjects without night shifts excluded)
% of long spells of consecutive night shifts	Proportion (%) of >4 consecutive night shift spells during the year / all spells of consecutive daily night shifts
Time between shifts (hours)	The average time between work shifts (hour) during the year (time between shift and free day or other absence excluded)
% of short shift intervals	Proportion (%) of shift intervals of ≤11 hours during the year/ all shift intervals
% of short recovery periods after the last night shift	Proportion (%) of <28 hours recovery periods after the last night shift during the year/ all recovery periods after the last night shift
Social aspects of working hours	
% of annual leave days	Proportion (%) of annual leave days/ annual contract days
% of weekend work	Proportion (%) of Saturday and/or Sunday work/ all week-ends
% of single free days	Proportion (%) of single free days/all free days
Variability of shift starting times	MAD of shift starting times. The mean absolute deviation (MAD) is the average distance of the data set from its mean, calculated as the mean of the absolute deviations about the data's mean (65)
Variability of shift ending times	MAD of shift ending times
Variability of shift length	MAD of shift lengths
% of realized shift plans	Proportion (%) of all realized annual shifts /all planned shifts (based on the comparison of the planned and finalized shift plans)
% of the use of shift wishes	Proportion (%) of wished shifts/all shifts
% of realized shift wishes	Proportion (%) of realized shift wishes /all shifts

working hours was 35.3 hours, the maximum mean weekly working hours ranging from 45–48 hours. Few subjects, mostly physicians, had single calendar weeks with working hours of up to 92 hours (including some 24 hour shifts). There were considerable differences in the shift characteristics between the nursing personnel's day work and shift work contracts and physicians' working time contracts.

The interrelationships between different working time variables within each working time domain are shown in table 4. With few exceptions, the correlations were mostly low, indicating that the variables measured different aspects of working hours. High correlations were seen between % of long shifts and % of long night shifts (r=0.76) and the correlation between % of night shifts and % of non-day shifts (r=0.83).

Occurrence and prevalence

In order to decide the optimal algorithms for the exposure to potentially health-relevant aspects of working hour patterns, we calculated annual prevalence rates for different cut-off values related to the annual occurrence rates (at least once a year, and >10%, >25% , and >50% of the annual occurrence). As shown in table 5, depending on the occurrence, ie, the cut-off value chosen, the annual prevalence of the exposure variables among shift workers varied remarkably. For example, 93% of

Table 3. Description of the working time variables among the final analytical sample including 4631 employees with a work contract of at least 10 months and with the minimum of 150 working days in 2013 [Md=median; Min=minimum; Max=maximum; SD=standard deviation]

Working time domain/variable	Nursing personnel Day work contract (N=1702)					Nursing personnel Shift work contract (N=2400)					Physicians Physicians' work time contract (N=529)				
	Mean	SD	Md	Min	Max	Mean	SD	Md	Min	Max	Mean	SD	Md	Min	Max
Length of working hours															
Weekly working hours (hours)	34.9	2.8	35.4	16.0	45.0	34.7	2.5	35.2	17.8	47.8	35.3	2.9	35.8	23.9	46.0
% of long (> 40 hours) working weeks	14	16	9	0	86	26	11	26	0	78	14	19	4	0	83
% of long (> 48 hours) working weeks	1	3	0	0	65	5	7	2	0	57	1	5	0	0	67
Shift length (hours)	7.8	0.5	7.7	3.8	9.8	8.5	0.8	8.3	4.6	12.4	7.8	0.4	7.7	5.5	10.1
% of long shifts	0	1	0	0	25	5	13	1	0	97	0	1	0	0	16
Length of night shifts (hours)	10.6	2.7	10.7	2.9	17.0	10.8	0.9	10.8	2.5	24.5	12.7	4.3	12.3	7.0	17.8
% of long night shifts	24	39	0	0	100	9	25	0	0	100	53	51	67	0	100
Time of the day (% of)															
Early morning shifts	4	6	2	0	27	9	11	2	0	38	2	3	1	1	5
Morning shifts	29	37	6	0	100	37	23	39	0	100	2	9	0	0	100
Day shifts	70	37	92	0	100	27	27	17	0	100	98	10	100	0	100
Evening shifts	1	4	0	0	32	19	14	21	0	95	0	1	0	0	18
Night shifts	0	2	0	0	36	15	19	12	0	99	0	0	0	0	1
Non-day shifts	2	5	0	0	59	34	25	38	0	99	1	2	0	0	30
Shift intensity															
Number of consecutive working days	5.1	0.4	5.2	2.9	7.4	4.7	0.5	4.7	3.1	8.1	5.2	0.4	5.3	2.9	5.9
% of long spells of work shifts	1	2	0	0	22	5	4	5	0	25	0	1	0	0	7
Number of consecutive night shifts	3.5	0.9	3.0	2.0	6.0	4.0	0.7	4.0	2.0	7.6	2.6	0.5	3.0	2.0	3.0
% of long spells of consecutive night shifts	1	3	0	0	15	5	7	1	0	42	0	0	0	0	0
Time between shifts (hours)	15.6	2.6	16.0	0	20.2	14.9	3.0	15.5	0	19.5	15.7	2.3	16.2	0	18.7
% of short shift intervals	1	4	0	0	48	19	14	19	0	99	1	3	0	0	29
% of short recovery periods after the last night shift	34	43	0	0	100	6	14	0	0	100	100	0	100	100	100
Social aspects of working hours															
% of annual leave days	13	4	13	0	29	12	4	13	0	34	11	5	12	0	24
% of weekend work	3	7	0	0	60.4	41	18	45	0	91	0	2	0	0	15
% of single free days	4	4	2	0	35	17	9	16	0	63	3	3	2	1	31
Variability of shift starting times	0.4	0.6	0.2	0	5.1	3.3	1.5	3.7	0	6.7	0.1	0.2	0	0	2.5
Variability of shift ending times	0.7	0.5	0.6	0	4.9	3.1	1.4	3.2	0	7.0	0.4	0.4	0.3	0	3.4
Variability of shift length	0.5	0.3	0.5	0	5.0	1.0	0.8	0.8	0	10.9	0.5	0.4	0.3	0	3.2
% of realized shift plans	92	18	98	0	100	89	18	93	0	100	96	16	100	0	100
% of the use of shift wishes	2	6	1	0	78	7	12	2	0	100	1	0	1	1	1
% of realized shift wishes	0	2	0	0	29	3	5	1	0	53	0	0	0	0	0

the subjects had at least one night shift in 2013, but the night shifts covered >25% of all the annual shifts only among 23% of the shift workers.

Stability and time trends of working time variables

Comparison between the years showed that working time variables within individuals were relatively stable from 2008–2013 (table 6), as shown by the mostly high year-to-year correlation coefficients ranging, from r=0.7–0.9 in 23 variables. The correlations decreased only moderately up to five years between the analyzed two years. The year-to-year correlation coefficients for rarely occurring variables (eg, % of early morning shifts, % of short recovery after the last night shifts) were lower, from r=0.4–0.6 showing lower stability.

Discussion

Epidemiological research on working hours and health has increased rapidly but the findings have been inconsistent. Transfer to electronic management systems, including the growing use of the electronic payroll and shift planning systems, has created new possibilities for access and analysis of exact exposure data on working hours in large epidemiological studies. The future possibilities to link objective exposure assessment of working time patterns to follow-up of morbidity and mortality will be a major step forward in the research of working hours and health. In this paper, we developed general algorithms for the assessment of 29 variables describing working time patterns to be used in future epidemiological studies on working hours, shift work and health.

These variables capture four major domains of working time patterns (length of the working hours, time of the day, shift intensity, and social aspects of working

Table 4a. Between correlations of variables of annual working time patterns within each working time domain in 2013 for the final analytical sample limited to nursing personnel with a shift work contract of ≥10 months and with ≥150 working days in 2013, N=2400.

Length of working hours (%)	Correlation coefficient			
	Long (>40 hours) working week (%)	Long (>48 hours) working week (%)	Long shift (%)	Long night shift (%)
Long (>40 hours) working week	1.00			
Long (>48 hours) working week	-0.40	1.00		
Long shift	0.24	-0.11	1.00	
Long night shift	0.12	0.003	0.76	1.00

Table 4b. Between correlations of variables of annual working time patterns within each working time domain in 2013 for the final analytical sample limited to nursing personnel with a shift work contract of ≥10 months and with ≥150 working days in 2013, N=2400.

Time of day (%)	Correlation coefficient				
	Early morning shift (%)	Morning shift (%)	Day shift (%)	Evening shift (%)	Night shift (%)
Early morning	1.00				
Morning	0.21	1.00			
Day	0.13	-0.63	1.00		
Evening	-0.39	-0.38	-0.38	1.00	
Night	-0.26	-0.27	-0.43	0.50	1.00
Non-day	-0.40	-0.37	-0.48	0.89	0.83

Table 4c. Between correlations of variables of annual working time patterns within each working time domain in 2013 for the final analytical sample limited to nursing personnel with a shift work contract of ≥10 months and with ≥50 working days in 2013, N=2400.

Shift intensity (%)	Correlation coefficient			
	Long spells of work shifts (%)	Long spells of consecutive night shifts (%)	Short shift intervals (%)	Short recovery periods after the last night shift (%)
Long spells of work shifts	1.00			
Long spells of consecutive night shifts	0.25	1.00		
Short shift intervals	0.04	-0.41	1.00	
Short recovery periods after the last night shift	0.06	-0.06	-0.04	1.00

Table 4d. Between correlations of variables of annual working time patterns within each working time domain in 2013 for the final analytical sample limited to nursing personnel with a shift work contract of ≥10 months and with the ≥150 working days in 2013, N=2400.

Social aspects of working hours (%)	Correlation coefficient				
	Annual leave days (%)	Weekend work (%)	Single free days (%)	Realized shift plans (%)	Use of shift wishes (%)
Annual leave days	1.00				
Week-end work	-0.12	1.00			
Single free days	0.04	0.40	1.00		
Realized shift plans	0.10	-0.02	-0.01	1.00	
Use of shift wishes	-0.003	0.13	-0.04	-0.02	1.00
Realized shift wishes	-0.02	0.14	-0.01	0.004	0.98

hours) which are based on the current understanding and evidence on the potential pathways of how working hours could influence physical and psychosocial health. The possible pathways from shift work to decreased health can be related to psychosocial, behavioral, or physiological mechanisms (2, 9). Since working hours are associated with different types of health outcomes and psychosocial problems, and we do not know yet which of the developed variables prove to be the most important ones, we suggest here a wide range of potential algorithms for the future studies. However, the selection of the exposure variables should be based on specific hypotheses and outcomes of the study and if this were not the case, the analyses should be corrected for multiple testing. All 29 working time pattern variables have been calculated for an annual time window due to the observed annual variation in the distribution of free-time and operational working hours linked to the many of used variables. The annual time window is also sufficiently long to allow a reliable estimation and follow-up of the used working time exposure variables.

The first domain, *length of the working hours* included algorithms for the annual, weekly or daily working hours calculated for each year separately. The selection of this domain and the variables designed can be justified by the fact that the length of the working hours needs to be related to the variation of cumulative work load if the work intensity itself is not modified. There is also good evidence of the association of long work shifts, long working weeks and long annual working hours with ill health, safety and work-home balance (7, 16, 17, 21, 43–45). The second domain, *time of the day*, includes the annual proportion of the different shifts; and the third domain, *shift intensity* includes several variables related to the number of consecutive work shifts and recovery time between the shifts. Studies have shown that night shift work is related to circadian dysrhythmia due to the changed exposure to environmental light and other circadian time cues (2, 37). Earlier studies have also indicated the effects of non-standard work shifts (especially night shifts and early morning shifts), and shift intensity (including factors like the speed and

Table 5. Prevalence of the percentile working time variables depending on the cut-off value of the occurrence of the variable in 2013 for the final analytical sample limited to nursing personnel with a shift work contract of ≥10 months and with the ≥150 working days in 2013, N=2400).

Working time domain	% of annual occurrences			
	≥1	>10	>25	>50
Length of working hours				
Long (>40 hour) working weeks	56	40	33	26
Long (>48 hour) working weeks	66	56	30	16
Long shifts	82	13	2	1
Long night shifts	100	18	2	0
Time of the day				
Early morning shifts	38	28	19	2
Morning shifts	97	64	52	39
Day shifts	98	68	43	17
Evening shifts	51	36	30	21
Night shifts	93	37	23	12
Non-day shifts	96	65	53	38
Shift intensity				
Long spells of work shifts	18	11	8	5
Long spells of consecutive night shifts	29	15	8	1
Short shift intervals	48	35	28	19
Short recovery periods after the last night shift	100	14	7	0
Social aspects of working hours				
Annual leave days	19	16	15	13
Week-end work	70	59	52	45
Single free days	42	29	22	16
Realized shift plans	100	98	96	93
Use of shift wishes	84	17	8	2
Realized shift wishes	32	8	3	1

direction of shift rotation and recovery time between the shifts) on sleep and health (22, 45–48), Indeed, good conceptual (48) and epidemiological (49–51) support exists on the role of sufficient recovery in terms of sleep, health, and well-being. Besides the early morning and nights shifts, fixed evening work may also be associated with dissatisfaction with working hours and increased risk for sick leaves.

The last domain s*ocial aspects of working hours* includes variables related to the distribution of free days, irregularity and predictability of the working hours and working time control. These aspects of working hours are closely related to the organization of work and the possibilities to influence free-time. Evidence also shows that fewer free weekends and more frequent single free days are associated with lower work satisfaction and subjective well-being (19, 52–54). As indicated by recent reviews, there are both theoretical and empirical reasons to assume that working time control would be an important factor for work-life balance, health and well-being (55, 56). In epidemiological studies, working time control has predicted subjective health, sickness absence, disability pensions and later retirement (57–59).

In addition to the use of average annual values of a working time variable (eg, average time between

shifts during the whole year), we also suggest the use of dichotomized variables. The dichotomized variables have two components: the specified cut-off level and its frequency during the year. The cut-off levels (eg, long working hours being >48 hours a week) are mostly arbitrary and need to be re-defined when outcome data are available. There is some evidence on a few of the cut-offs suggesting, for example that >4 consecutive night shifts (weekly rotating shifts) are related to an increased health risk (21, 34–36). The suggested cut-off points of 40 and 48 hours for "long" and "very long" weekly working hours, 12 hours for "long" work shifts and the definition of 11 hours for "short" time between shifts are based on the existing European legislation and cut-offs used by many recent studies (51, 60–62). Based on the sensitivity analysis, we recommend the use of ≥25% occurrence when calculating prevalence for the individual variables. In relation to night shifts and quick returns, the use of 25% occurrence level means in practice >1 night shift or quick return in a week. This is more often than in the Nurses's Health Study (24) where night shift work was defined as ≥3 night shifts in a month.

The use of objective exposure data would be a substantial improvement to the exposure assessment methods used in previous research on working hours and health. Most of the earlier studies have used questionnaires to assess exposure; this method is more prone for bias than objective register data. Many of the variables we suggest are similar to those used in earlier questionnaire studies. These variable are, for example, the weekly working hours, shift length, length of night shifts, number of consecutive working days and time between shifts. On the other hand, some of the variables are new since it is practically impossible to measure them in questionnaire studies (eg, the % of single free days or the % of realized shift wishes). Objective exposure data are naturally more precise than questionnaire data allowing determination of eg, the exact annual occurrence of night shifts (% of night shifts) for each year for all the subjects. Although it is possible that the "toxicity" of night work does not accumulate similarly as the toxicity of, for example, lead or other heavy metals, it is still the proportion of the night shifts, taking also into account the recovery aspect that is hypothesized to be important for the chronic health effects of shift work. To confirm this, further studies linking the different precisely measured exposure variable to health outcomes are needed.

The methodology used to retrieve and analyze the raw working hour data from employers' registers proved to be valid. The retrieval of the data was easy, and the retrieved data included no wrong, missing, or outdated working hour data. The incorrect duplicate data were mostly due to the same employees attached to two different rotas having two separate rota codes but no or minimal differ-

Table 6. Correlation coefficients of all the 29 annual working time variables averaged for all year to year combinations for the final analytical sample including employees with a work contract of at least 10 months and with the minimum of 150 working days per a year.

Working time domain	Correlation coefficient (years)				
	Year-to-year	2	3	4	5
Length of working hours					
Weekly working hours (hours)	0.74	0.63	0.54	0.48	0.43
% of long (>40 hours) working week	0.82	0.76	0.71	0.67	0.62
% of long (>48 hours) working week	0.44	0.38	0.36	0.33	0.27
Shift length (hours)	0.93	0.87	0.81	0.77	0.72
% of long shifts	0.91	0.85	0.80	0.75	0.68
Length of night shifts (hours)	0.50	0.44	0.46	0.35	0.29
% of long night shifts (%)	0.81	0.78	0.75	0.70	0.65
Time of the day (% of)					
Early morning shifts	0.68	0.38	0.09	0.20	0.68
Morning shifts	0.95	0.91	0.87	0.84	0.81
Day shifts	0.96	0.93	0.90	0.87	0.85
Evening shifts	0.94	0.91	0.87	0.83	0.80
Night shifts	0.94	0.89	0.84	0.81	0.78
Non-day shifts	0.93	0.89	0.85	0.83	0.79
Shift intensity					
Number of consecutive working days	0.79	0.71	0.67	0.62	0.59
% of long spells of work shifts	0.83	0.79	0.75	0.71	0.69
Number of consecutive night shifts	0.89	0.84	0.81	0.78	0.75
% of long spells of consecutive night shifts	0.88	0.81	0.75	0.71	0.65
Time between shifts (hours)	0.52	0.29	0.20	0.14	0.10
% of short shift intervals	0.91	0.86	0.82	0.78	0.74
% of short recovery periods after the last night shift	0.45	0.57	0.51	0.52	0.46
Social aspects of working hours					
% of annual leave days	0.55	0.46	0.40	0.35	0.33
% of week-end work	0.94	0.90	0.86	0.84	0.81
% of single free days	0.88	0.83	0.80	0.76	0.73
Variability of shift starting times	0.96	0.93	0.90	0.87	0.84
Variability of shift ending times	0.95	0.92	0.89	0.86	0.83
Variability of shift length	0.86	0.80	0.75	0.72	0.69
% of realized shift plans	0.70	0.40	0.28	0.24	0.17
% of the use of shift wishes	0.78	0.68	0.61	0.55	0.50
% of realized shift wishes	0.76	0.65	0.58	0.52	0.47

ences in the actual working hours during a specific day. The duplicate data was easy to detect and delete or correct automatically. The created working time variables showed no unexpected distributions or significant outliers compared to previous smaller Finnish studies (41, 42). In rare cases, nurses who had a shift work contract did not have any night or evening shifts while some nurses with a day work contract were working during the nights. The results were logical based on the occasional delays in contract updating, as informed by the hospitals. The used working time variables were reasonably stable over the years,

except for two variables with a very rare occurrence.

The use of an objective registry-based exposure assessment method does not fully substitute the use of questionnaire-based information on working hours since factors like the perceived control of working hours and the use of non-paid overtime work cannot be estimated from company records. Information on specific individual factors related to adaptation to night work, like chronotype, is also useful as such factors can modify the health effects of shift work (63). However, the registry data have several advantages, including continuous exposure information with no selection bias covering virtually all employees and no attrition (30, 36, 37). It also offers a possibility to analyze irregular, complex and changing working time patterns over long periods of time that are common in organizations, such as hospitals [eg, (64)]. Since the current knowledge on the effects of working time patterns on health is mostly based on crude methods on exposure assessment, it is likely that the use of the proposed more detailed register-based exposure information will create robust new knowledge on the association of working time patterns with health. Detailed exposure information is also essential in planning intervention studies to assess whether change in working time patterns could reduce morbidity or the other negative effects of shift work or unfavorable working hours.

To conclude, the data retrieval method used and the suggested algorithms allows a detailed characterization of working time patterns potentially relevant for health. For multidimensional exposure assessment, we suggest the measurement of four potentially health-relevant areas of working time patterns: the length of the working hours, time of the day, shift intensity, and the social aspects of the working hours. We propose that the developed method is considered as "a method for choice" to assess exposure to working time patterns in large-scale observational studies on working hours and health.

References

1. Night work (women) convention concerning employment of women during the Night. International Labour Organization (ILO), 1919.

2. Straif K, Baan R, Grosse Y, Secretan B, El Ghissassi F, Bouvard V, et al. Carcinogenicity of shift-work, painting, and fire-fighting. Lancet Oncol. 2007;8(12):1065–6. http://dx.doi.org/10.1016/S1470-2045(07)70373-X.

3. Kolstad HA. Nightshift work and risk of breast cancer and other cancers--a critical review of the epidemiologic evidence. Scand J Work Environ Health. 2008;34(1):5–22. http://dx.doi.org/10.5271/sjweh.1194.

4. Kamdar BB, Tergas AI, Mateen FJ, Bhayani NH, Oh J. Night-shift work and risk of breast cancer: a systematic review and meta-analysis. Breast Cancer Res Treat. 2013;138(1):291–301. http://dx.doi.org/10.1007/s10549-013-2433-1.

5. Ijaz S, Verbeek J, Seidler A, Lindbohm ML, Ojajarvi A, Orsini N, et al. Night-shift work and breast cancer--a systematic review and meta-analysis. Scand J Work Environ Health. 2013;39(5):431–47. http://dx.doi.org/10.5271/sjweh.3371.

6. Jia Y, Lu Y, Wu K, Lin Q, Shen W, Zhu M, et al. Does night work increase the risk of breast cancer? A systematic review and meta-analysis of epidemiological studies. Cancer Epidemiol. 2013;37(3):197–206. http://dx.doi.org/10.1016/j.canep.2013.01.005.

7. Wagstaff AS, Sigstad Lie JA. Shift and night work and long working hours--a systematic review of safety implications. Scand J Work Environ Health. 2011;37(3):173–85. http://dx.doi.org/10.5271/sjweh.3146.

8. Frost P, Kolstad HA, Bonde JP. Shift work and the risk of ischemic heart disease - a systematic review of the epidemiologic evidence. Scand J Work Environ Health. 2009;35(3):163–79. http://dx.doi.org/10.5271/sjweh.1319.

9. Puttonen S, Härmä M, Hublin C. Shift work and cardiovascular disease - pathways from circadian stress to morbidity. Scand J Work Environ Health. 2010;36(2):96–108. http://dx.doi.org/10.5271/sjweh.2894.

10. Vyas MV, Garg AX, Iansavichus AV, Costella J, Donner A, Laugsand LE, et al. Shift work and vascular events: systematic review and meta-analysis. BMJ. 2012;345:e4800. http://dx.doi.org/10.1136/bmj.e4800.

11. Knutsson A, Boggild H. Gastrointestinal disorders among shift workers. Scand J Work Environ Health. 2010;36(2):85–95. http://dx.doi.org/10.5271/sjweh.2897.

12. Pan A, Schernhammer ES, Sun Q, Hu FB. Rotating night shift work and risk of type 2 diabetes: two prospective cohort studies in women. PLoS Med. 2011;8(12):e1001141. http://dx.doi.org/10.1371/journal.pmed.1001141.

13. Puttonen S, Oksanen T, Vahtera J, Pentti J, Virtanen M, Salo P, et al. Is shift work a risk factor for rheumatoid arthritis? The Finnish Public Sector study. Ann Rheum Dis. 2010;69(4):779–80. http://dx.doi.org/10.1136/ard.2008.099184.

14. Hedstrom AK, Akerstedt T, Hillert J, Olsson T, Alfredsson L. Shift work at young age is associated with increased risk for multiple sclerosis. Annals of neurology. 2011;70(5):733–41. http://dx.doi.org/10.1002/ana.22597.

15. Li WQ, Qureshi AA, Schernhammer ES, Han J. Rotating night-shift work and risk of psoriasis in US women. J Invest Dermatol. 2013;133(2):565–7. http://dx.doi.org/10.1038/jid.2012.285.

16. Bannai A, Tamakoshi A. The association between long working hours and health: a systematic review of epidemiological evidence. Scand J Work Environ Health. 2014;40(1):5–18. http://dx.doi.org/10.5271/sjweh.3388.

17. Virtanen M, Heikkila K, Jokela M, Ferrie JE, Batty GD, Vahtera J, et al. Long working hours and coronary heart disease: a systematic review and meta-analysis. Am J Epidemiol. 2012;176(7):586–96. http://dx.doi.org/10.1093/aje/kws139.

18. Kivimäki M, Virtanen M, Kawachi I, Nyberg ST, Alfredsson L, Batty GD, et al. Long working hours, socioeconomic status, and the risk of incident type 2 diabetes: a meta-analysis of published and unpublished data from 222 120 individuals. Lancet Diabetes Endocrinology. 2015;3(1):27–34. http://dx.doi.org/10.1016/S2213-8587(14)70178-0.

19. Albertsen K, Rafnsdóttir G, Grimsmo A, Tómasson K, Kauppinen K. Workhours and worklife balance. Scand J Work Environ Health. 2008;5(Suppl):14–21.

20. Bara AC, Arber S. Working shifts and mental health--findings from the British Household Panel Survey (1995-2005). Scand J Work Environ Health. 2009;35(5):361–7. http://dx.doi.org/10.5271/sjweh.1344.

21. Jansen NW, Kant I, Nijhuis FJ, Swaen GM, Kristensen TS. Impact of worktime arrangements on work-home interference among Dutch employees. Scand J Work Environ Health. 2004;30(2):139–48. http://dx.doi.org/10.5271/sjweh.771.

22. Driscoll TR, Grunstein RR, Rogers NL. A systematic review of the neurobehavioural and physiological effects of shiftwork systems. Sleep Med Rev. 2007;11(3):179–94. http://dx.doi.org/10.1016/j.smrv.2006.11.001.

23. Hansen J, Stevens RG. Case-control study of shift-work and breast cancer risk in Danish nurses: impact of shift systems. Eur J Cancer. 2012;48(11):1722–9. http://dx.doi.org/10.1016/j.ejca.2011.07.005.

24. Schernhammer ES, Kroenke CH, Laden F, Hankinson SE. Night work and risk of breast cancer. Epidemiology. 2006;17(1):108–11. http://dx.doi.org/10.1097/01.ede.0000190539.03500.c1.

25. Schernhammer ES, Laden F, Speizer FE, Willett WC, Hunter DJ, Kawachi I, et al. Rotating night shifts and risk of breast cancer in women participating in the nurses' health study. J Natl Cancer Inst. 2001;93(20):1563–8. http://dx.doi.org/10.1093/jnci/93.20.1563.

26. Lie JA, Roessink J, Kjaerheim K. Breast cancer and night work among Norwegian nurses. Cancer Causes Control. 2006;17(1):39–44. http://dx.doi.org/10.1007/s10552-005-3639-2.

27. Steenland K, Fine L. Shift work, shift change, and risk

of death from heart disease at work. Am J Ind Med. 1996;29(3):278–81. http://dx.doi.org/10.1002/(SICI)1097-0274(199603)29:3<278::AID-AJIM8>3.0.CO;2-M.

28. Taylor PJ, Pocock SJ. Mortality of shift and day workers 1956-68. Br J Ind Med. 1972;29(2):201–7.

29. Schwartzbaum J, Ahlbom A, Feychting M. Cohort study of cancer risk among male and female shift workers. Scand J Work Environ Health. 2007;33(5):336–43. http://dx.doi.org/10.5271/sjweh.1150.

30. Costa G, Haus E, Stevens R. Shift work and cancer - considerations on rationale, mechanisms, and epidemiology. Scand J Work Environ Health. 2010;36(2):163–79. http://dx.doi.org/10.5271/sjweh.2899.

31. Ward BW. Implications of using different measures of work shift in survey research. Journal of Applied Social Science. 2011;5(1):62–77.

32. Wang XS, Travis RC, Reeves G, Green J, Allen NE, Key TJ, et al. Characteristics of the Million Women Study participants who have and have not worked at night. Scand J Work Environ Health. 2012;38(6):590–9. http://dx.doi.org/10.5271/sjweh.3313.

33. Hansen J, Lassen CF. Nested case-control study of night shift work and breast cancer risk among women in the Danish military. Occup Environ Med. 2012;69(8):551–6. http://dx.doi.org/10.1136/oemed-2011-100240.

34. Härmä M. Workhours in relation to work stress, recovery and health. Scand J Work Environ Health. 2006;32(6):502–14. http://dx.doi.org/10.5271/sjweh.1055.

35. Härmä M, Kecklund G. Shift work and health - how to proceed? Scand J Work Environ Health. 2010;36(2):81–4. http://dx.doi.org/10.5271/sjweh.2902.

36. Papantoniou K, Kogevinas M. Shift work and breast cancer: do we need more evidence and what should this be? Occup Environ Med. 2013;70(12):825–6. http://dx.doi.org/10.1136/oemed-2013-101630.

37. Stevens RG, Hansen J, Costa G, Haus E, Kauppinen T, Aronson KJ, et al. Considerations of circadian impact for defining 'shift work' in cancer studies: IARC Working Group Report. Occup Environ Med. 2011;68(2):154–62. http://dx.doi.org/10.1136/oem.2009.053512.

38. Kivimäki M, Gimeno D, Ferrie JE, Batty GD, Oksanen T, Jokela M, et al. Socioeconomic position, psychosocial work environment and cerebrovascular disease among women: the Finnish public sector study. Int J Epidemiol. 2009;38(5):1265–71. http://dx.doi.org/10.1093/ije/dyn373.

39. Rahm E, Do H. Data Cleaning: Problems and Current Approaches. IEEE Data Eng. Bull. 2000;23 (4):3-13.

40. Gschwandtner T, Gärtner J, Aigner W, Miksch S. A Taxonomy of Dirty Time-Oriented Data. Lecture Notes in Computer Science (LNCS 7465): Multidisciplinary Research and Practice for Information Systems (Proceedings of the CD-ARES 2012). 2012.

41. Hakola T, Paukkonen M, Pohjonen T. Less quick returns--greater well-being. Ind Health. 2010;48(4):390–4. http://dx.doi.org/10.2486/indhealth.MSSW-02.

42. Järvelin-Pasanen S, Ropponen A, Tarvainen M, Paukkonen M, Hakola T, Puttonen S, et al. Effects of implementing an ergonomic work schedule on heart rate variability in shift-working nurses. J Occup Health. 2013;55(4):225–33. http://dx.doi.org/10.1539/joh.12-0250-OA.

43. de Castro AB, Fujishiro K, Rue T, Tagalog EA, Samaco-Paquiz LP, Gee GC. Associations between work schedule characteristics and occupational injury and illness. Int Nurs Rev. 2010;57(2):188–94. http://dx.doi.org/10.1111/j.1466-7657.2009.00793.x.

44. Folkard S, Lombardi DA, Tucker PT. Shiftwork: safety, sleepiness and sleep. Ind Health. 2005;43(1):20–3. http://dx.doi.org/10.2486/indhealth.43.20.

45. Sallinen M, Kecklund G. Shift work, sleep, and sleepiness - differences between shift schedules and systems. Scand J Work Environ Health. 2010;36(2):121–33. http://dx.doi.org/10.5271/sjweh.2900.

46. Bambra CL, Whitehead MM, Sowden AJ, Akers J, Petticrew MP. Shifting schedules: the health effects of reorganizing shift work. Am J Prev Med. 2008;34(5):427–34. http://dx.doi.org/10.1016/j.amepre.2007.12.023.

47. Neil-Sztramko SE, Pahwa M, Demers PA, Gotay CC. Health-related interventions among night shift workers: a critical review of the literature. Scand J Work Environ Health. 2014;40(6):543–56. http://dx.doi.org/10.5271/sjweh.3445.

48. Geurts SA, Sonnentag S. Recovery as an explanatory mechanism in the relation between acute stress reactions and chronic health impairment. Scand J Work Environ Health. 2006;32(6):482–92. http://dx.doi.org/10.5271/sjweh.1053.

49. Kivimäki M, Leino-Arjas P, Kaila-Kangas L, Luukkonen R, Vahtera J, Elovainio M, et al. Is incomplete recovery from work a risk marker of cardiovascular death? Prospective evidence from industrial employees. Psychosom Med. 2006;68(3):402–7. http://dx.doi.org/10.1097/01.psy.0000221285.50314.d3.

50. van Amelsvoort LG, Kant IJ, Bültmann U, Swaen GM. Need for recovery after work and the subsequent risk of cardiovascular disease in a working population. Occup Environ Med. 2003;60 Suppl 1:i83–7. http://dx.doi.org/10.1136/oem.60.suppl_1.i83.

51. Flo E, Pallesen S, Moen BE, Waage S, Bjorvatn B. Short rest periods between work shifts predict sleep and health problems in nurses at 1-year follow-up. Occup Environ Med. 2014;71(8):555–61. http://dx.doi.org/10.1136/oemed-2013-102007.

52. de Bloom J, Geurts SA, Sonnentag S, Taris T, de Weerth C, Kompier MA. How does a vacation from work affect employee health and well-being? Psychol Health. 2011;26(12):1606–22. http://dx.doi.org/10.1080/08870446.2010.546860.

53. Geiger-brown* J, Muntaner C, Lipscomb J, Trinkoff A. Demanding work schedules and mental health in nursing assistants working in nursing homes. Work & Stress. 2004;18(4):292–304. http://dx.doi.org/10.1080/02678370412331320044.

54. Karhula K, Härmä M, Sallinen M, Hublin C, Virkkala J, Kivimäki M, et al. Association of job strain with working

hours, shift-dependent perceived workload, sleepiness and recovery. Ergonomics. 2013;56(11):1640–51. http://dx.doi.org/10.1080/00140139.2013.837514.

55. Joyce K, Pabayo R, Critchley JA, Bambra C. Flexible working conditions and their effects on employee health and wellbeing. Cochrane Database Syst Rev. 2010(2):Cd008009.

56. Nijp HH, Beckers DG, Geurts SA, Tucker P, Kompier MA. Systematic review on the association between employee worktime control and work-non-work balance, health and well-being, and job-related outcomes. Scand J Work Environ Health. 2012;38(4):299–313. http://dx.doi.org/10.5271/sjweh.3307.

57. Ala-Mursula L, Vahtera J, Pentti J, Kivimäki M. Effect of employee worktime control on health: a prospective cohort study. Occup Environ Med. 2004;61(3):254–61. http://dx.doi.org/10.1136/oem.2002.005983.

58. Vahtera J, Laine S, Virtanen M, Oksanen T, Koskinen A, Pentti J, et al. Employee control over working times and risk of cause-specific disability pension: the Finnish Public Sector Study. Occup Environ Med. 2010;67(7):479–85. http://dx.doi.org/10.1136/oem.2008.045096.

59. Virtanen M, Oksanen T, Batty GD, Ala-Mursula L, Salo P, Elovainio M, et al. Extending employment beyond the pensionable age: a cohort study of the influence of chronic diseases, health risk factors, and working conditions. PLoS One. 2014;9(2):e88695. http://dx.doi.org/10.1371/journal.pone.0088695.

60. Hannerz H, Albertsen K. Long working hours and subsequent use of psychotropic medicine: a study protocol. JMIR research protocols. 2014;3(3):e51.

61. Costa G, Anelli MM, Castellini G, Fustinoni S, Neri L. Stress and sleep in nurses employed in "3 x 8" and "2 x 12" fast rotating shift schedules. Chronobiol Int. 2014;31(10):1169–78. http://dx.doi.org/10.3109/07420528.2014.957309.

62. Boivin DB, Boudreau P. Impacts of shift work on sleep and circadian rhythms. Pathologie-biologie. 2014;62(5):292–301. http://dx.doi.org/10.1016/j.patbio.2014.08.001.

63. Papantoniou K, Castano-Vinyals G, Espinosa A, Aragones N, Perez-Gomez B, Burgos J, et al. Night shift work, chronotype and prostate cancer risk in the MCC-Spain case-control study. Int J Cancer. 2014 Dec 20. [Epub ahead of print]

64. Pijpe A, Slottje P, van Pelt C, Stehmann F, Kromhout H, van Leeuwen FE, et al. The Nightingale study: rationale, study design and baseline characteristics of a prospective cohort study on shift work and breast cancer risk among nurses. BMC Cancer. 2014;14:47. http://dx.doi.org/10.1186/1471-2407-14-47.

65. Bohle P, Willaby H, Quinlan M, McNamara M. Flexible work in call centres: Working hours, work-life conflict & health. Appl Ergon. 2011;42(2):219–24. http://dx.doi.org/10.1016/j.apergo.2010.06.007.